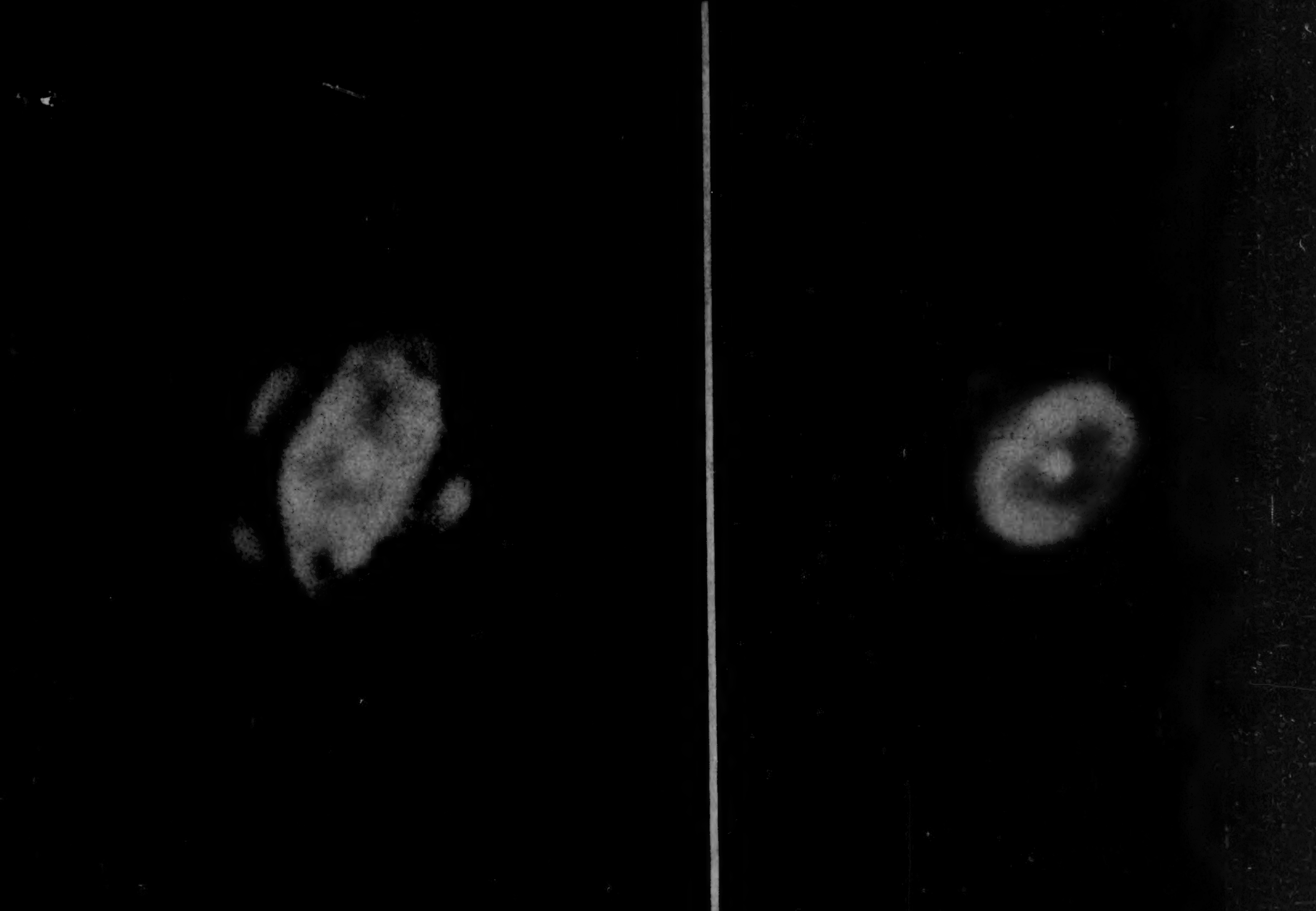


Two Planetary

The Editors Note . .

Dr. John Q. Stewart's opening remarks at the New Haven conference on navigation are worthy of special thought:

NAVIGATION, broadly defined, is the science and art of determining the paths of human activity in space. Astronomy is pre-eminently the science of space. Therefore, in these days of stress astronomers teach navigation.

Marine and air navigation form an extensive and important field, but I hold that it is not enough for scholars who understand space and time and number to be teaching navigation only in its more concrete and obvious aspects. Space and time, number and physical power, are the setting for major enterprises of the modern world. These physical things are too little understood and regarded by statesmen. In large measure the tragedy of our period is ascribable to lack of quantitative leadership in the United States and the British Empire. Social and political problems, although always requiring qualitative and humane judgments, cannot be handled successfully nowadays unless quantitative mechanical analyses are emphasized.

To train junior officers of the armed services in marine and air navigation will be of inadequate avail unless senior political strategists, when they gather in the chart room and on the bridge of the ship of world state, are solidly trained in political navigation. It was astronomy which first recognized that man lives on a planet; and realistic dealing with the conditions of planetary life takes precedence today over every other responsibility of physical science. The numbers of the peoples, the sizes and the material resources of their homelands, the distances which separate them and the routes and vehicles which join them—these are quantitative political elements which have been largely ignored at horrible cost.

Instead of contributing to clarification of political navigation, physical scientists in Great Britain and the United States have been befogging it. Last September, for example, the British Association for the Advancement of Science sponsored with considerable publicity a Conference on Science and the World Order. One of the pronouncements given official prominence was that distance has been "virtually abolished" by present-day technology. That half-truth turned out shortly afterward to be a most dangerous lie, as brave men unsupported far from home learned at Hong Kong, Singapore, Batavia, Manila, and Mandalay. I venture to assert that in situations which involve competition among geographically distributed agencies, the distance factor always will remain a primary control. Examination of the influence of distance in human relations is one of the definite social studies to which an astronomer can contribute.

The doctrine that distance has been abolished by technology stirred approving echoes last fall on this side of the Atlantic, and it is tommyrot. The recent U. S. Army-Navy report on the progress of the war significantly states, "In engaging in an amphibious war, world-wide in extent, tremendous distances, both by air and by sea, immediately became a primary factor."

JOHN Q. STEWART

Sky and TELESCOPE

CHARLES A. FEDERER, JR., *Editor* HELEN SPENCE FEDERER, *Managing Editor*

In Focus

THE front and back covers this month carry photographs of three planetary nebulae. The Ring nebula is a familiar object, usually cited as a typical planetary; those on the front cover are less well known, but equally important in the study of these unusual celestial objects. These two are labelled in Norton's *Star Atlas* according to Herschel, who said that it would probably require "ages of observation" to estimate the condition of the planetaries, a prediction partially borne out by Lawrence H. Aller's report of progress to date.

In all three cases a star is visible at the center of the diffuse disk of the nebula. These central stars are among the hottest known, and it is believed they furnish the energy by which the surrounding nebulosity shines. In the Ring nebula, the central star is of apparent magnitude 14.7, and about 75,000° K. hot; in N.G.C. 7662, it is 80,000° K; and in N.G.C. 7009, 50,000° K. In the last two cases the central stars are probably about one-third the diameter of the sun—they show continuous spectra.

The inner ring of N.G.C. 7662 measures 14″ x 17″, and its outer ring, 28″ x 32″; in N.G.C. 7009, these dimensions are 26″ x 30″ and 26″ x 44″, respectively. The Ring nebula measures 59″ x 83″. All three objects are about 9th magnitude photographically. Notice the faint extensions or ansae on N.G.C. 7009—it is sometimes called the Saturn nebula.

The Ring nebula's distance is about 5,300 light-years, according to Berman, and its dimensions, 97,000 x 136,000 astronomical units. The corresponding figures for N.G.C. 7662 and 7009 are, respectively: 4,000 and 3,000 light-years; 34,000 x 38,000 and 24,000 x 41,000 astronomical units. These two have masses about 1/10 the sun's, excluding the central star. All are expanding, at rates between 15 and 25 kilometers per second.

VOL. I, NO. 10

CONTENTS

AUGUST, 1942

COVER: Two planetary nebulae, N.G.C. 7009 (left) and N.G.C. 7662 (right). The first is in Aquarius, near R.A. 23h 22m, Dec. +42°; the second is in Andromeda, at R.A. 21h, Dec. —12°. Both were photographed with the 60-inch reflector at Mt. Wilson Observatory—N.G.C. 7009 on July 13, 1912, exposure 3½ hours; N.G.C. 7662 on October 17, 1911, exposure 1½ hours. These planetaries are discussed in "In Focus" (above) and in "Ages of Observation" (page 11).

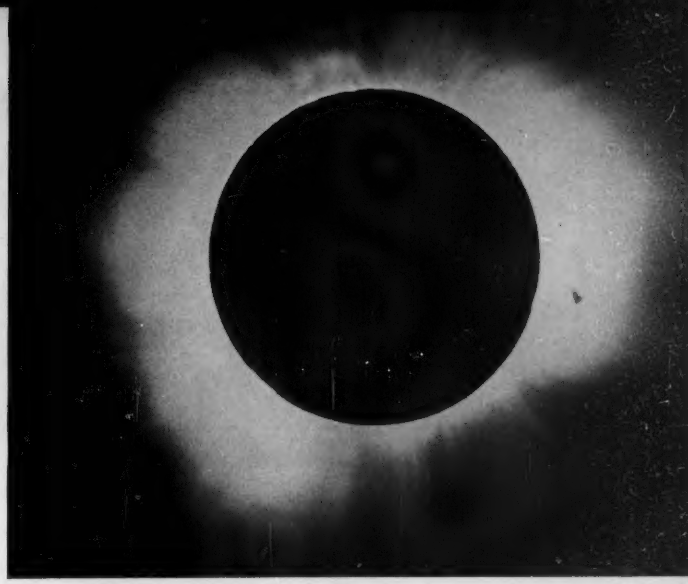
BACK COVER: The Ring nebula in Lyra, N.G.C. 6720, photographed on August 5, 1921, with the 100-inch telescope at Mt. Wilson, exposure 1 hour. It is a fine object for small telescopes, situated between β and γ Lyrae, near R.A. 18h 50m, Dec. +33°. See "In Focus" (above) and "Ages of Observation" (page 11).

SKY AND TELESCOPE is published monthly by Sky Publishing Corporation. Entered as second class matter, April 28, 1939, at the Post Office, New Rochelle, N. Y., under Act of March 3, 1879. Publication office: Manchester, N. H.; re-entry as second class matter at the Post Office, Manchester, N. H., pending.
Subscription: $2.00 per year in the United States and possessions; $2.50 foreign (including Canada). Single copies: 20 cents. Make checks and money orders payable to Sky Publishing Corporation. Send subscription orders and notice of change of address (10 days in advance) to editorial and general offices: Harvard College Observatory, Cambridge, Mass.

FACTS ABOUT ECLIPSES

By William H. Barton, Jr.

The eclipse of the moon on the 25th of this month will be widely observed. In the Hayden Planetarium and here the ever-fascinating story of eclipses is featured. *See pages 10 and 20 for further material on this month's event.*

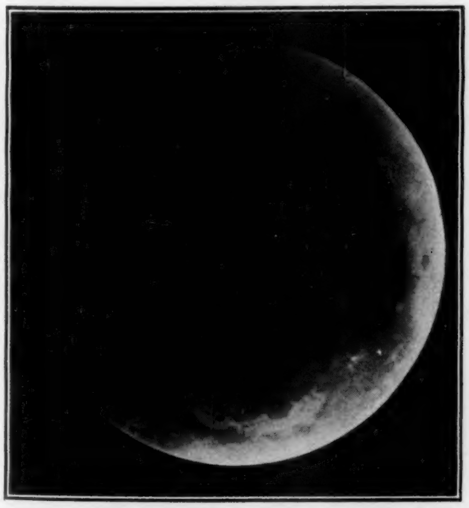


A total eclipse of the sun.

It is generally difficult to set the date of the beginning of a branch of learning. Scraps of knowledge do not roll off an assembly line as automobiles used to, numbered consecutively. The first solar eclipse to be seriously studied in this country was, no doubt, that of June 24, 1778, observed by David Rittenhouse. But Edmond Halley saw one in London in 1715. The great Tycho Brahe recorded his impressions of the eclipse of August 21, 1560, in Copenhagen, when he was but a boy 14 years of age. The story of Columbus' lunar eclipse of February 29, 1504, is well known. Then we can go on back through classical times, biblical times, and to the ancient Chinese, Chaldeans, and Babylonians. The haze of the distant past gradually envelops this procession and there is no beginning to be recorded.

Several thousand years ago the Chaldeans could predict eclipses. They had knowledge of a cycle known as the saros, which means repetition. These early people knew a great deal about the motions of the sun and moon.

Suppose we review the problem of the occurrence of eclipses. The earth travels around the sun in an elliptical path, varying in its distance from about 91 million to 94 million miles. From the earth, then, the apparent size of the sun changes. It appears relatively smaller in July, when we are at our greatest distance (aphelion), and larger when we are close to it in January (perihelion). The moon likewise revolves around the earth in an ellipse, at an average distance of 238,900 miles, sometimes as near as 222,000, and again as far as 253,000. The moon varies in apparent size even more than the sun, since its distance change between perigee and apogee is proportionately greater.



An eclipse of the moon.

If we observe the moon near a certain star tonight, the interval until the moon comes back to that same star again is $27^d\ 7^h\ 43^m\ 11^s.5$, about 27.3 days. In the meanwhile the earth has moved a considerable distance in its path around the sun. Therefore, if you were observing from the sun, additional time would be required to bring the earth and moon back to the same relative position in which we found them at the beginning of our study. Looked at from the earthly point of view, the time when the moon and sun are lined up (new moon) until they are lined up at the next new moon is $29^d\ 12^h\ 44^m\ 2^s.8$, about 29.5 days. These two months are termed *sidereal* and *synodic*, respectively.

As seen from the earth, the moon does not follow the sun's path through the sky. The lunar orbit is tilted to the ecliptic plane about five degrees, a value first determined by Hipparchus several thousand years ago. The places where the moon's path cuts the sun's path are the nodes. For the sun or the moon to be eclipsed it must be near one of these nodes. The length of time required for the moon to travel from a node back again to the same node is another interval, the *nodical* month. Its length is $27^d\ 5^h\ 5^m\ 35^s.8$.

Sometimes this is called a draconic month. This term harks back to the ancient times when the accepted explanation for a solar eclipse was that a dragon was swallowing the sun. On some occasions, the nodical month became the time elapsing between the draconic swallows. The sign for "node" reflects the same quaint belief and is supposed to indicate the head and tail of a dragon. The ascending node, where the moon passes from south to north of the ecliptic, or sun's path (which, of course, derives its name as the path of eclipses), is ☊, and descending node, where the moon goes from north to south, is marked thus, ☋.

The old philosopher, Hipparchus, was also aware of the fact that the interval between one perigee passage and the next following perigee has still another length. It is now measured as $27^d\ 13^h\ 18^m\ 33^s.1$, and is known as the *anomalistic* month.

Just as there are different kinds of months, so there are different kinds of years. The ordinary year, or tropical year, is the interval between successive passages of the sun across the tropics or the equinoxes. Its length is $365^d\ 5^h\ 48^m\ 46^s.08$, about 365.24 mean solar days.

If we measure the interval between the sun's passage over one of the moon's nodes and the next passage, it is $346^d\ 14^h\ 53^m$, about 18.6 days less than a tropical year. The nodes move around the ecliptic opposite to the direction of the sun's motion and therefore the "eclipse year" is shorter by that rather considerable amount.

For comparison we can tabulate:

247 nodical months	= 6585.3572 days
239 anomalistic months	= 6585.5374 days
223 ordinary months	= 6585.3211 days
19 eclipse years	= 6585.7806 days

These multiple intervals, you see, are the same length within a small fraction of a day, and equal about 18 years and 11 days, if four leap years intervene, or 18 years, 10 days, if five leap years intervene. This period is roughly the saros, which, strictly speaking, is the period of 223 ordinary months, or 18 years, 10 1/3 (or 11 1/3) days. This period brings the sun and moon in about the same relative positions with respect to the earth. An eclipse, therefore, is repeated every 18 years and 10 or 11 days. The third of a day changes the position of a solar

A series of photographs of the annular eclipse of April 7, 1940, made by the Texas Observers, shows the moon not quite covering the sun's bright disk.

eclipse track on the earth by about 120 degrees of longitude westward.

On June 8, 1937, the Hayden Planetarium sent a party to Peru to photograph the total eclipse visible over western South America and the Pacific Ocean. The "same" eclipse occurred previously, May 29, 1919, when the third of a day made the 1919 eclipse visible over Africa, the Atlantic Ocean, and South America. On June 20, 1955, the saros will bring the eclipse to Ceylon, Siam, and the Philippines. In 1973, South America and Africa will see another repetition on June 30th. And so it goes! (See page 10 for the saros story of this month's lunar eclipse.)

Since eclipses can occur only when the sun and moon are near the nodes at the same time, there are well-defined limits within which the sun and moon must be in order to effect an eclipse. At the earth's average distance from the sun, about 93 million miles, our planet's shadow stretches 857,000 miles. The moon then passes through the earth's shadow at a point where the shadow has a diameter, on the average, of nearly 5,800 miles, more than 2⅔ times the diameter of the moon. We must not forget that the earth's distance from the sun varies, thus lengthening and shortening the earth's shadow. Variation of the moon's distance is another factor which throws great variety into eclipses of the moon. A lunar eclipse, moreover, is not necessarily central.

There may be no lunar eclipses in a calendar year, and there are never more than three.

In the similar fashion, the moon's shadow on the earth varies, depending upon the distances involved. The moon's shadow averages 231,650 miles in length, varying 4,000 miles above and below this figure. The average distance of the moon is about 239,000. Therefore, when the shadow is at its shortest, it will not reach the earth by about 4,000 miles. This produces an *annular* eclipse, one in which the moon appears smaller than the sun, leaving a ring of sunlight, or an annulus—hence the name, annular. Many people mistakenly associate the word with annual and believe such an eclipse happens every year.

From our earth, the sun and moon appear so nearly the same size that had the moon been only slightly smaller or farther away, or the sun been larger and nearer, we might never have known of such an event as a total eclipse of the sun. The moon's shadow is only 163 miles wide at best, and no total eclipse of the sun can last more than 7½ minutes. Generally, it is much shorter.

The eclipse of June 8, 1937, was a 7-minute eclipse. In order to see it at its maximum length, an observer had to be at sea on the broad Pacific Ocean. It was the good fortune of one party of scientists to be aboard ship at the right place at the right time. Not only did they observe the eclipse for the maximum period, but slightly in excess of the maximum. The ship was headed in the same direction as the shadow, therefore they stayed within the shadow longer than the shadow needed to pass a given point. Small boys who follow a parade hear the band play longer than those who merely stand and watch.

If an observer could travel as fast as the moon's shadow, he might observe quite a long eclipse, but the shadow goes at least 1,000 miles an hour.

The greatest work on eclipses is a book published in 1887 by T. R. von Oppolzer, a Viennese astronomer. This *Canon of Eclipses* gives data concerning 8,000 solar eclipses and 5,200 lunar eclipses. The time covered runs from 1207 B.C. to 2162 A.D. Maps show the approximate paths of the eclipses of the sun, and sufficient data is given to check up and discuss these events in a rather comprehensive way.

There are about 238 eclipses of the sun in 100 years, on the average. Only 28 per cent of these are total, and therefore of much interest to the astronomer. However, about a third of all eclipses are of the annular variety. Next to a total eclipse, this is the most spectacular and interesting type. Rather rare is the annular-total eclipse. Here we have an annular eclipse in which the moon's shadow just fails to touch the earth over most of the path. But near the center of the path, toward the noon point, the shadow just touches and a total eclipse is observed. Only four per cent of all eclipses are of this sort, and it is a most interesting variety from the layman's point of view, if not from the scientific.

Total eclipses, of interest to the scientist, are really unusual events. Of the ones that happen, many pass across the polar regions or the oceans. Seldom, indeed, are they in suitable places for study. But when they do occur in some accessible place, about once in three years, expeditions go out in spite of war and other obstacles. The average length of an eclipse is less than three minutes, so total eclipse time is valuable. To observe totality for an hour, an astronomer must travel all over the world and have perfect weather on a score of "special occasions."

Certain things are visible during a total solar eclipse that, generally speaking at least, are not visible under ordinary circumstances. Ordinarily when we look at the sun, we see the photosphere, the bright visible surface of the sun. Above this, however, is a red layer, that Young compares to "a sheet of scarlet fire," which was called the *chromosphere* (color sphere) by Frankland and Lockyer in 1869. Its redness is actually caused by a predominance of hydrogen in intensely hot, glowing clouds—not burning in the usual sense of the word. Airy in 1842, followed by Proctor and others, chose the name "sierra," but it has never been popularly adopted.

Extending above the chromosphere are long tongues of glowing hydrogen gas and detached clouds of the same character. These are called *prominences*, a name first applied to them in 1842. At that time, there was some doubt as to whether they belonged to the sun, moon, earth, or were mere optical illusions.

The ancients seem to have missed seeing these red protuberances that are so plainly visible during a total eclipse. The first recorded observation is no doubt the one made by the Swedish astronomer, Vassenius, in 1733. He noticed three or four small pinkish clouds entirely detached from the edge of the moon and, as he supposed, floating in the lunar atmosphere. This eclipse occurred long after the telescope was in use for astronomical purposes and it is not clear

whether or not it was used for this discovery.

The chromosphere was detected even earlier. Capt. Stannyan, observing an eclipse at Berne in 1706, noticed that for six or seven seconds before the sun emerged, a red streak of light was seen around the moon's limb.

All doubt about the objectivity of the prominences was removed in 1860, when Secchi and De la Rue successfully photographed them. Their real nature was a mystery until the eclipse of August 18, 1868, during which the spectroscope was used to analyze them. This eclipse, then, might be said to have ushered in modern eclipse technique.

Observations of the corona, that halo of pearly light that is seen surrounding the sun during a total eclipse, date back to antiquity. Philostratus and Plutarch describe it unmistakably. Yet it is still a mystery. Today, progress is being made on photographing the corona without waiting for an eclipse.

As the sun goes into totality, the last narrow strip of light is frequently broken up into many tiny points, as though the sunlight were shining through perforations. These are commonly called Baily's beads. They were observed by Francis Baily at an eclipse on May 15, 1836, which was not total, but annular. He described the effects as follows: "When the cusps of the sun were about 40 degrees asunder, a row of lucid points, like a string of bright beads, irregular in size and distance from each other, suddenly formed round that part of the circumference of the moon that was about to enter, or which might be considered as having just entered on the sun's disk. Its formation indeed was so rapid that it presented the appearance of having been caused by the ignition of a fine train of gunpowder."

Another peculiar phenomenon seen at an eclipse are shadow bands. These are wavy rippling lines that flit across the landscape at the beginning and end of totality. No doubt they are atmospheric, but the matter is still one under a great deal of discussion. They were noticed as early as 1820 by Goldschmidt. So far they have defied photography. When they appear, the light is growing dim and the degree of contrast in them is very low. There is no emulsion of sufficiently high speed and high contrast to catch them. On some occasions they are rather prominent and on others almost invisible.

Physicists, such as cosmic-ray investigators, are interested in eclipses, too. The radio investigator now goes on eclipse trips to study conditions in the invisible, but audible, world of waves. Technique has changed since the early days. But an eclipse is still an eclipse, and until the end of time scientists will probably chase them over the world to snatch those rare few moments of totality.

ASTRONOMICAL ANECDOTES

SQUARING THE CIRCLE; STARS BY DAY

THERE has come to my desk a modest brochure professing to overthrow all the rules of geometry. It is, essentially, another attempt to square the circle (or to determine an exact value for π), and the author says that it is the result of "many years of profound study and computation." I can say only what De Morgan did, when he saw the same statement in an angle-trisection: "Very likely, and very sad." De Morgan actually recommended one simple rule to avoid the use of that endless 3.141592653589793 . . . . "From three diameters of the circle deduct eight thousandths and seven millionths of a diameter, then to the result add five per cent." This is a trifle small, but the error is of the order of two inches in the circumference of the earth.

To remember a value of this indispensable constant which is sufficiently accurate to compute the circumference of a circle as large as the earth's orbit with an error of only about 1/100 of an inch, we count the number of letters in each word of the following:

How I wish I could recollect, of circle round,
The exact relation Archimedes found.

But we must remember that the philosopher's name, in Greek with a χ in place of *ch*, would have only nine letters; further, "found" should have eight letters, not five.

In the above we do get a rhyme, which is more than we can say for the one which is good enough to state the circumference of the observable universe to the nearest million miles. It is attributed to an English physicist who went to California to lecture during the days of prohibition, and again we count the number of letters in each word:

How I wish a drink, alcoholic of course, after the heavy chapters involving quantum mechanics!

The diameter of the observable universe is one billion light-years, or roughly, 6×10^{21} miles.

There have come in a few objections (one anonymous but very positive) to any conclusion that stars cannot be seen by day, at least with the ease that one might suppose from the oft-repeated statement about observation from the "bottom of a well." One correspondent, H. M. H., tells me that in 1897, at the age of 10, she and her 12-year-old brother, her father, and some workmen, all saw a star from the bottom of an 80-foot chimney (which was to be the pier for a 9-inch telescope!) in Dunkirk, N. Y. She says, "Of course, we may have been mistaken, but the memory and view are strong in my mind's eye."

Dunkirk has a latitude of about $+42°$ $29'$; so its zenith has that declination, too. An 80-foot chimney, if about five feet in diameter, will permit an area of the sky about seven degrees in diameter to be seen from the bottom of it. Therefore, the star must have been between declinations $+39°$ and $+46°$. There are only three stars which, under any conceivable circumstance except that of a total eclipse, could have been seen by day from the bottom of that chimney: Vega, magnitude 0.1, Capella, 0.2, and Deneb Cygni, 1.3. I have great doubts about the last-named star because of its relative faintness, and there would not be great probability of either of the others being conveniently at hand. If we knew the date and the hour of the observation, we could decide which star it might be.

I have seen Sirius by day with the naked eye during April of this year, after setting a telescope on the star's position. My postcard reporting this observation for inclusion in the May "Anecdotes," where this subject was discussed, reached the editors after the issue had gone to press.

Another letter comes from E. J. Stull, master of the S.S. *Collingsworth* of the American Mail Line. (May they keep the sea-lanes open.) He has used a sextant to get a four-line celestial fix in bright sunlight, observing Jupiter, Venus, the moon, and the sun. This I don't doubt in the least—the smallest optical aid, at sea level, will suffice to reveal Jupiter and Venus most of the time.

Capt. Stull goes on to say that "first magnitude stars are plainly visible at noonday with the unaided eye in clear weather from mountains of 12,000 feet elevation or more, the height necessary depending of course on the clarity of the atmosphere." That I don't doubt either; the sky grows darker with increasing altitude above sea level, permitting the pupil of the eye to dilate far enough for a bright star to be seen. Also, there is considerably less scattered light than at low altitudes, where dust and dirt, as well as most wells and chimneys, are.

I hope Dr. F. L. Whipple can soon organize his "Harvard expedition to the bottom of a well," so we can have some modern data from which to judge the hearsay reports from the past. My own evidence may not be accepted, but I can say this: Recently we have been making changes in a tower telescope completely enclosed, the vertical length of which is 80 feet. At the top is a circular opening eight inches in diameter, in which the lens, temporarily removed, formerly rested. From the bottom of *this* 80-foot chimney the sky is very, very bright.

R.K.M.

THE TEACHING OF NAVIGATION

A conference on this subject was held by the Teachers of Astronomy at New Haven in June, on the occasion of the meeting of the American Astronomical Society. Co-leaders of the discussion were Drs. Stewart and Pierce, of Princeton University Observatory. Dr. Stewart's introductory remarks appear on page 2, under "The Editors Note."

BY JOHN Q. STEWART

AT Princeton, a term's instruction in *The Elements of Marine and Air Navigation* has just been completed by about 160 undergraduates. For a number of years, an outline of marine navigation has been included in the course in elementary astronomy. In addition, since the fall of 1939, instruction in air navigation has been given to the student pilots in the civilian air programs. Dr. Pierce and I came to this meeting of teachers prepared to learn rather than to teach; but, notwithstanding the poverty of our practical experience in navigation, our point of view as regards a number of matters has become fairly definite.

Pretraining in navigation, at any rate by the better-equipped colleges, of students who expect to enter the Navy or Army Air Corps is thoroughly worthwhile. The Princeton course, as regards its purpose and content, has received the approval of high officials in the Navy. Navigation is a big subject, and the time at the disposal of the Service schools is inadequate to ensure the thorough mastery even of its paperwork.

Naturally, little more than the paperwork can be taught within four walls, and there is no quick and easy substitute for long experience on the water or in the air. However, the Service schools are in great need of instructors in the paperwork of navigation; and a number of the best students in the college courses are going to find themselves assigned to instructors' posts.

But it must be emphasized that no course at all in navigation is better than a course which starts the student off with bad computing habits and misleading ideas. Therefore, it is not surprising that the Services, in some of their public pronouncements to colleges and schools, have seemed to decry technical pretraining. Standard courses in algebra and trigonometry, even though over-abstract, at least are given by well-prepared instructors.

The unified and simultaneous presentation of marine and air navigation has been experimented with very successfully at Amherst, Princeton, and Haverford, and no doubt elsewhere. Prof. Warren K. Green joins with Dr. Pierce and myself in the conclusion that an introductory course at the college level ought to treat both these phases of the single subject, navigation.

A considerable fraction of undergraduates likely to enroll in a college course do not know whether their later service will be at sea or in the air. The mathematical principles underlying air navigation are identical with those of marine navigation, and most of the methods of computation and plotting are the same. The problems of one lend perspective to problems of the other. With the growing cooperation between surface ships and air forces, there is a growing necessity for mutual understanding among navigators.

Navigation does not require a preliminary course in trigonometry and logarithms, far less in spherical trigonometry. Such subjects are a necessity for the individual who invents new navigational methods, but in this emergency navigation must be presented as an operational routine. Time is not available for an excess of theory. We must be practical and modern. Graphical methods, linear interpolation, and judgment of tolerances should be stressed.

To teach rule-of-thumb procedures is unnecessary. There is much to be said for retaining navigation permanently in curricula of liberal arts colleges after this emergency is over, because for the non-scientific majority of undergraduates it provides an attractive blend of theoretical and applied thinking. Its concrete quantitative procedures open the door to a new intellectual world for many men whose training otherwise has been purely qualitative.

The importance of standard Hydrographic Office terminology. The craftsman can afford to be impatient with standardization, but standardization is a necessity for mass production. The Hydrographic Office of the U. S. Navy gives continuous professional attention to elaboration of the best navigational methods and to the standardization of navigational terminology. No comparable agency exists for problems of civilian air pilots and of Army air navigators. Indeed, none ought to be necessary, since navigation is one single discipline, not two, and since the Hydrographic Office has been not unmindful of problems of the air.

We regard it as unfortunate that manuals of navigation have been written for civilian and Army pilots which depart unnecessarily from standard methods and nomenclature. The college

Rapid improvements in air navigation techniques and observing instruments make it difficult for civilian instructors to choose the best material for short courses.

teacher will do well to guide on "Bowditch" (H.O. 9), the *Navy Aircraft Manual* (H.O. 216), the *Maneuvering Board Manual* (H.O. 217), and the encyclopedia "Dutton."

Six divisions of navigation. Apart from the important difference between observation and calculation, most authorities list four divisions of navigation: piloting, dead reckoning, radio aids to navigation, and celestial navigation. We would suggest that the sailings and problems of relative motion rank as two additional divisions. The sailings are of decreasing interest, but problems of relative motion—that is, interception and the like in the air, and maneuvering in formation for surface ships—are of growing importance and interest.

Our Princeton course, and Prof. Green's excellent course at Amherst, feature problems of relative motion.

Astronomy provides the principal background for only one of these six divisions. So I must conclude, on a somewhat low pitch, that whatever contributions astronomy may make to the exact and social sciences, most of navigation gets along beautifully without any astronomy!

SOME COMMENTS

BY NEWTON L. PIERCE

INCLUSION of the elements of both air and marine navigation in one course, as has been done at Princeton and elsewhere, involves covering a very considerable amount of material. In order that so broad a field may be covered effectively, great care in the organization and presentation of material is essential. It may therefore be of some value to survey briefly certain phases of the subject in the light of our experience at Princeton.

1. *Piloting.* Experienced navigators will question the amount of piloting which can be taught in the classroom, and rightly so, for piloting is inevitably tied up with seamanship for the marine navigator, and with airmanship for the pilot. In fact, piloting is taught at some Service schools as a part of flight training, rather than in the classroom. However, there is a good deal which can be taught in the classroom, particularly familiarity with and use of charts, and the geometry of bearings. It is apparent that practice in the use of charts is of essential importance in a navigation course, and the fact that chart navigation is more and more replacing computational methods lends emphasis to this.

For purposes of teaching piloting, we have found satisfactory the New York Harbor chart on a scale of 1:40,000 and the New York sectional aeronautical chart on a scale of 1:500,000, both of which students are required to purchase. In addition, a large collection of navigational charts of various types, and covering various portions of the earth, is of great aid to the student. No amount of reading about charts will so well apprise the student of the many navigational aids available.

2. *Dead Reckoning.* Presentation of this subject requires the use of one or more types of plotting sheets. We have found that pads of Weems' Universal Plotting Sheets and one or two H.O. Position Plotting Sheets serve well for each student's use. In addition, several other types of plotting sheets were on hand, so that students might familiarize themselves with the available types. Navy schools have emphasized to us the importance of teaching students to plot bearings and distances accurately and neatly, and we have therefore placed considerable emphasis on this phase of the work.

3. *Relative Motion* has been underemphasized and often badly garbled in the various texts which treat of it at all. It is true that the relative-motion problem has little use in peacetime marine navigation. It is, however, of great importance in wartime, for fleet maneuvers and for convoy sailing, and is important at all times for the air navigator.

In our opinion, a clear presentation of relative-motion problems, using the simple vector solution, should form an essential element of the course. We find that the relation of the movement plot, the relative-movement plot, and the vector diagram of velocities, is not an easy one for the student to understand and will permit considerable emphasis. Likewise, the similarity of air and sea problems and the use of the one simple vector solution for the various sorts of air problems (radius of action, alternate airport, operations from a moving base, interception, and search) require emphasis. The combination of the vector diagram with a movement plot, as a number of texts present the subject, we have tried and found seriously confusing. We have reached the conclusion that complete separation of the movement plot from the vector diagram makes for clarity and quicker understanding. In this connection, a uniform notation, namely that used by the Navy, is a very great help. Complicated geometrical solutions of these problems, and trigonometrical solutions, are so much slower than the simple vector solution as to warrant no consideration.

In connection with the subject of relative motion, it is worthwhile to mention the use of the Maneuvering Board diagram (H.O. 2665a) and its offspring, the Mark III Aircraft Navigational Plotting Board. These greatly simplify the solution of problems. Furthermore, for those who are training to be aerial navigators, an understanding of the use of the Plotting Board and of other aircraft computers, notably the Dalton Model J used by the Air Corps, is important. An excellent treatment of the use of the Maneuvering Board diagram is presented in the *Maneuvering Board Manual* (H.O. 217).

4. *Radio Navigation.* This is a broad field in itself, and much time can be spent on the subject. However, due to the limited time available in a one-semester course, we have found it necessary to confine ourselves largely to the problem of plotting radio bearings. This involves some understanding of the inherent errors of radio bearings, including deviation corrections of the radio direction-finder, and the correct plotting of such bearings with corrections for convergence of the meridians on the Lambert chart or for conversion angle properly applied on the Mercator chart.

5. *Celestial Navigation.* The availability of H.O 214 for the solution of the astronomical triangle greatly simplifies the handling of celestial observations. We have placed our main emphasis on this method of solution as have all Service schools. It is possible that some acquaintance with other tables, such as those of Ageton, Dreisonstok, and Weems, needs to be given, but the old cosine-haversine method is far too cumbersome for modern navigation and should certainly be abandoned in present training programs. It is also our opinion that the simplicity and ease of use of the *Air Almanac* strongly recommend it over the more cumbersome *Nautical Almanac*, even at sea. We have, however, featured the *Nautical Almanac* in our course during the past semester because of its use in some Service schools.

The question of how much training should be given on various navigational instruments presents a difficult problem. Some practice with the sextant and bubble octant would be of great value, but the time limit imposed by a one-semester course precludes any effective drill. Use of sextants with an artificial horizon is, we are convinced, not worth the time it requires. Those who can

CORRECTION TO JULY ISSUE

Through typographical error, the references on page 4, column 2, to 14,000 angstroms and 24,000 angstroms are incorrect; these should read 140,000 angstroms and 240,000 angstroms, respectively.—ED.

give students an opportunity to make a few sextant shots with a water horizon are fortunate. At Princeton we have had to content ourselves with the use of an artificial sun mounted in the hallway. This work, ably directed by Mr. Sturges, at least gives each student an opportunity to handle and read a sextant. In addition to this, Prof. Russell has supervised bubble-sextant observations for a considerable number of students.

6. *Problems.* We are convinced that a navigation course must involve the working of many problems. In no other way can a student adequately understand the subject—this applies equally to instructors. Good navigation patently requires a real familiarity with the mechanics of using navigational materials, and the more drill it is possible to give the student, the better he will understand the subject. That imagination and a world-wide viewpoint are important in the construction of problems goes without saying. Weekly sets of rather stiff problems have worked out most satisfactorily, even though we have not been able to give as much supervised drill as we would have liked.

In conclusion, it is our opinion that a college course in navigation designed for the present emergency should combine the methods of both marine and air navigation. It should be completely practical in method and viewpoint, and should present primarily those modern, rapid methods which are actually in use by the Services. Furthermore, and this is perhaps of greatest importance, such a course should be guided in content and method by the procedures and needs of the Service schools.

Amateur Astronomers

AMATEURS OF SCIENCE

By Harold Stenbock

PAYNE, Minn., is a small country settlement 40 miles northwest of Duluth. Perhaps 30,000 years ago the country was swept by the waters of glacial Lake Upham; this left the immediate surroundings of Payne flat and boggy and little suitable for farming, and accounts for the slow growth of the community. The higher elevations of the land display till-plain characteristics. Around the shoreline of the ancient lake is a deposit of fine sand; farther out the bottom is covered with blue glacial clay, and the deeper places are now filled with peat bogs. In certain places, the bogs are covered with a dense growth of black spruce, tamarack, and white cedar, making them excellent habitats for wild life. The country is such as to direct the thinking mind to an interesting study of science.

In the fall of 1937, certain young people of Payne asked the writer to conduct a series of lectures in astronomy, and a class was started which met one evening a week. Soon the class organized into a club with the name, Amateurs of Science, and this later incorporated under the laws of Minnesota. At first there were 24 members in the club, mostly young people who had graduated from the nearby high school at Meadowlands, but a couple of them had a little college training. Since then, several changes have taken place in the membership; the present war conditions have taken away most of our original young men; some older people have stepped in to fill their places, and we try to keep our club in shape and spirit to serve the community as developing emergencies might require, until our young men come back home again.

The club built a planisphere of the sky as visible from the Payne horizon. A black silk thread represents the meridian. The sky map is fastened to a wheel, and turning the wheel makes the stars rise and set.

Early in 1938, the club started work on a 6-inch portable telescope. This was finished the following fall. It has a focal length of five feet, six inches.

When the telescope was made, a young man suggested building "an observatory to keep it in." This was approved at the annual meeting of the club in January, 1939, but the club had no money, no place to build, and no material. However, the Meadowlands Consolidated Schools had some school land at Payne which was leased to the club for the purpose, for one dollar a year. The members set themselves to cut logs and saw the lumber. The building project started on June 12, 1939. The building was to have a lecture room below, a dome for a 10-inch telescope above, and beside the dome a small den where the observer could spend the part of the night when not observing. The observatory is on a slight elevation of the otherwise flat country, giving good view of the sky.

All the work, and money for materials that had to be purchased, was donated. Before winter came, the building was erected so that the lecture room could be used. This is big enough for the club's purposes and when filled to capacity will hold from 30 to 40 people. Since then, the building has been improved a little each year, and it is now in good shape, but it has not yet been possible for the club to complete the dome for the telescope. In normal times that would come to perhaps $300, but the club has no money for the purpose, nor thinks it proper to undertake the construction until the war is over. With the dome installed, the building will cost, counting the work and the money that have been donated, about $1,000. According to its incorporation the club can never carry over $50 debts at any one time, and its policy is to transact business on a "pay as you go" basis.

Besides these astronomical project activities of the Amateurs of Science, a number of lectures have been given for the members.

But the Amateurs of Science have not tied themselves down strictly to astronomy. They have also started a small collection of natural history objects. An entire wall of the lecture room is planned to hold about 30 showcases.

During the past winter, lectures on conservation have also been given. Now we are busy with conservation of food through gardening. This will include lectures on garden soil, planting, care, control of plant disease, control of insect pests, and also actual garden projects, many of which are already started.

The club is also trying just now to have some member receive training and qualification to give Red Cross First Aid instruction at Payne and in surrounding communities during the present emergency.

Our club has a three-sided program—to observe, to conserve, and to serve.

The Amateurs of Science observatory still lacks its dome. Below is Charles Simpson's mill, where the lumber was cut; he is at the lever. Elmer J. Saari, president, is carrying the log. The group includes some members and their friends.

American Astronomers Report

Further papers from the American Astronomical Society meeting in June are summarized by the Editors.

New Companion Star

THE existence of a third component in the well-known double-star system of Mu Draconis was reported by Dr. K. Aa. Strand, of Sproul Observatory. This companion, although invisible, makes its presence known by regular fluctuations from the expected motion of the two visible components, over a period of three years. The fluctuations are caused by the gravitational attraction of the unseen star as it revolves around one of the visible stars.

Mu Draconis was discovered as a double with two equally bright components (magnitudes 5.80 and 5.83) by Sir William Herschel in 1779. From their relative motion since that time, it is believed that they revolve around each other once in about 1,500 years. At present they are near their closest approach, at about 70 times the distance sun-earth. The third star revolves around one of them at only three times the distance sun-earth, or about 250 million miles.

The new triple system is about 100 light-years away and has a mass of three and a half times the sun's; the unseen companion is a dwarf star with a mass about half that of the sun.

The accuracy of the photographic observations by which Dr. Strand detected these fluctuations is about 10 times as great as ordinary visual double-star observations.

An Important Binary System

BY means of the spectroscope, Dr. R. M. Petrie, of the Dominion Astrophysical Observatory, Victoria, B. C., has discovered another of the rare class of stars known as sub-dwarfs, this one being a component of the binary system HD 144208-9. It is of spectral class *A*, whereas the primary star is of class *G*, and a normal object for its class.

The luminosity of the sub-dwarf in terms of the primary was determined from the combined spectrum of the two stars, in which the metallic lines and the K line of calcium are weaker than normal, and the wings of the Balmer lines of hydrogen stronger. The assumption that the primary star obeys the mass-luminosity relation, whereby the mass of a star is proportional to its absolute magnitude, made it possible for Dr. Petrie to calculate the masses and mean densities of both stars.

There are many other binary systems which have solar (*G*-type) and *A* stars as components, and a study of these may produce many more sub-dwarfs. It is important that these systems be investigated, in order that we might learn more about the relationship of the sub-dwarfs to the white dwarfs, and the role of the former in the evolutionary sequence, Dr. Petrie's report stated.

Cyanogen

THE poisonous gas cyanogen seems to be a common constituent of the universe. It is found in interstellar space, in comets, and in the atmospheres of some stars. Its apparent conspicuousness in the spectra of stars having temperatures comparable to our sun has been used as an indication of the true luminosity or absolute magnitude of such stars, but not always as reliably as might be expected.

In recent work at Harvard, Dr. Dorrit Hoffleit has utilized newly available material on the proper (apparent) motions of the stars to test the validity of the application by F. Becker, of Germany, of the cyanogen criterion to stars in the $-45°$ zone. Dr. Hoffleit found that accurate measurements of cyanogen line-intensities on standardized plates of good quality yield absolute magnitudes superior to estimates based on spectral class alone. On the other hand, simple eye estimates on unstandardized objective-prism plates of faint stars are not necessarily adequate in telling whether or not a star is of high luminosity. Whereas stars identified by Becker as giants are almost invariably true giant stars, those provisionally assumed to be dwarfs are often erroneously so classified, Dr. Hoffleit said.

Star Distribution

OUR sun is definitely not in a region of subnormal density, according to available data on the reddening of distant stars, reported by Dr. Bart J. Bok, of Harvard, as one of the first results of work by the so-called "star-counting circuit," an informal organization of several observatories in this country and abroad.

A search for comparatively unobscured regions along the Milky Way has revealed the presence of several fields in which the light of the distant stars is only slightly dimmed by the absorption of interstellar matter. The most notable clear regions are in the constellations of Cepheus, Auriga, Monoceros, Carina, and Centaurus. The section of the Milky Way between the southern Coalsack and Cygnus, in which fall the star clouds of Sagittarius and Scutum, apparently contains no regions that are relatively unobscured. Even for the brightest patches in this section, the light of stars at 3,000 light-years from the sun is dimmed by one full magnitude.

The stars of different spectral classes are not well mixed in our part of the Milky Way, Dr. Bok said. For some classes, we find little variation in star densities; for others the densities drop off as we move away from the sun, but in no direction do we find marked increases. Perhaps the single, outstanding result is the rapid initial decrease in star densities for all classes in the direction of the galactic nucleus. Here the densities are very low at 1,000 light-years from the sun, and higher densities are not found for the central regions until we reach 3,000 to 5,000 light-years from the sun.

Progress in Emulsions

THE requirements of astronomers for photographic emulsions to meet their many and varied needs have been an important factor in the development of emulsions of use in other fields, both scientific and commercial. W. F. Swann, of the Eastman Kodak Research Laboratories, spoke on recent changes and improvements in spectroscopic plates. He mentioned in particular emulsion type Ia-O, which is probably the fastest blue-sensitive plate available when exposed for long periods to light of low intensity. Its graininess, however, limits it to use where grain is not of paramount importance, such as high-dispersion spectrograms.

Another emulsion which also has great speed in long exposures to weak light is type 103a. It has very fine granularity for its speed, and many observatories have reported it to be highly satisfactory.

Mr. Swann also called attention to emulsion type 548, which has extremely fine grain, and a resolving power better than 500 lines per millimeter.

Rotating Sectors

A NEW technique in photometry was discussed in a paper by Donald A. MacRae, reporting on work done at the Cook Observatory of the University of Pennsylvania.

In the accurate determination of the magnitudes of stars, it is important to be able to reduce a star's light by a known

(Continued on page 17)

SAROS FACTS

and the Lunar Eclipse

By Jesse A. Fitzpatrick

In the many excellent treatises on practical astronomy, we read of a time interval called the *saros*, which was discovered by the Babylonians several thousands of years ago, and used by them in predicting solar and lunar eclipses. I have never seen concrete evidence of the accuracy of predictions made in those days, but knowing the infallibility of the saros, I can readily understand how those stargazers of the dawn of civilization might have foretold the hour of a coming eclipse with only a small margin of error.

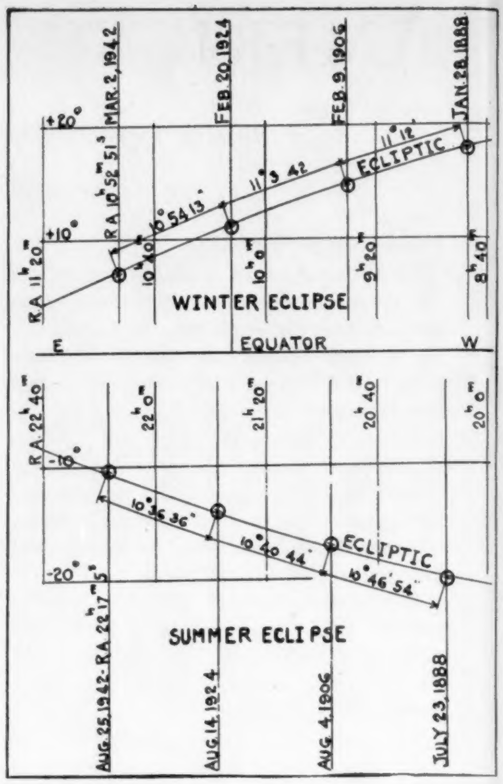
Each solar or lunar eclipse is part of a separate series beginning as a partial eclipse, visible near the north or south pole, increasing gradually to totality in temperate and tropical latitudes and then diminishing until it disappears at the opposite pole. The solar eclipse series lasts for about 1,300 years, and the lunar, about 870 years; the former contains 72 eclipses and the latter, 48. The recurrence of successive eclipses in any one series is at the end of the saros, which lasts 18 years, 10, 11, or 12 days (depending on whether there are five, four, or three leap years in the interval) and about eight hours. If we should observe an eclipse of the moon at midnight, a similar eclipse (the next in the 870-year series) will occur 18 years, 11 days, and eight hours later, but as this would happen at 8 o'clock in the morning, daylight would interfere with our observation of it. And the second recurrence would be at 4 o'clock in the afternoon. But the third saros period, making a total of 54 years and 34 days for the three intervals, will cause the eclipse to happen again at midnight.

These figures are not exact, due to the eccentricity of the moon's orbit and other disturbing factors, the explanations of which are outside the scope of this article. Of the two eclipses I shall discuss, one was only one hour and four minutes late at the end of three saros periods, and the other, one hour and 51 minutes early.

During the year 1942, there are two total lunar eclipses and three partial solar eclipses, each of which is in a separate series. Almanacs show a similar condition to have existed in the years 1888, 1906, and 1924. In each case a winter lunar eclipse is followed by a solar eclipse at the next new moon, and a summer lunar eclipse is preceded and followed by solar eclipses at the preceding and following new moons. The purpose here is to show the saros periods of the two lunar eclipses. All times given have been reduced to Eastern War Time.

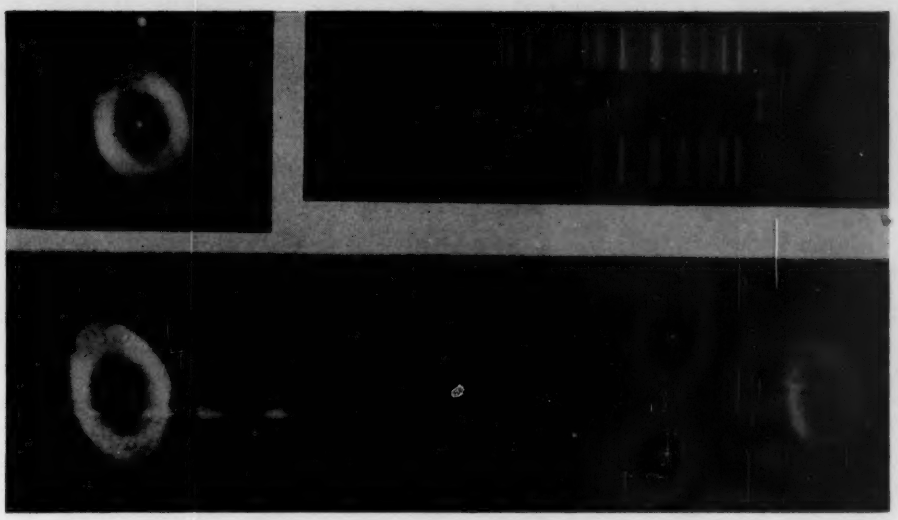
The accompanying table shows the principal elements and circumstances of the two eclipses which are necessary to compare the moon's motions through the earth's shadow at the end of each saros. On first inspection, it would appear that three saros periods equal 54 years and 33 days, instead of the 34 days stated above. The explanation of this discrepancy is that, in the case of the winter eclipse, the year 1888 was a leap year and the eclipse occurred before February 29th. If this 1942 summer eclipse happened only a few minutes later, the date would be August 26th. The year 1900 was not a leap year, which explains the 18 years and 12 days between 1888 and 1906. The saros from 1906 to 1924 included only four 29ths of February for the winter eclipse, but there were five for the summer eclipse.

On the diagram showing the eastward motion along the ecliptic, I have reduced all positions to the equinox of 1942, so as to show the exact distances traveled on the celestial globe. Since the equinox has moved westward three quarters of a degree in the 54 years, the relative positions would have varied considerably if they were not measured from an arbitrary position such as I have selected. I have retained in the drawing, however, the relative positions north or south of the ecliptic as they were at the time of each eclipse.



Since the table and diagram are self-explanatory, few comments are necessary, but I would suggest a careful examination of each to note the progressively increasing or decreasing times or distances in the successive saros periods. As an example, the distance from the earth to the moon increases about 720 miles for each saros of the winter eclipse, and decreases about the same distance for the summer eclipse. Also, note the slight change in the position angle of the points of contact of the moon with the earth's shadow, and the almost exactly equal durations of totality. In 1888, the summer eclipse had nearly the greatest magnitude possible, indicating about the center of this series.

Year	Date	Conjunction in R.A.	Middle of eclipse	Contact 1st pt.	Contact Last pt.	Moon's R.A.	Moon's decl.	Magnitude	N. or S. of ecliptic	Duration of totality	Earth-moon dist.--mi.
WINTER ECLIPSE											
1888	Jan. 28	7:22:03.6 p.m.	7:20:12 p.m.	93° E.	74° W.	8^h 43^m 53^s	+18° 1' 43"	1.647	-6' 29 "	1h 38.3m	234,148
1906	Feb. 9	3:49:58.5 a.m.	3:47:00 a.m.	96	71	9 28 22	+14 48 16	1.631	-7 7.9	1 38.4	234,828
1924	Feb. 20	12:12:25.7 p.m.	12:08:30 p.m.	97	67	10 11 18	+11 4 12	1.605	-8 1.6	1 37.8	235,505
1942	Mar. 2	8:26:36.4 p.m.	8:21:30 p.m.	98	64	10 52 51	+ 6 59 1	1.567	-9 18.7	1 36.6	236,227
SUMMER ECLIPSE											
1888	July 23	1:44:29.5 a.m.	1:44:48 a.m.	82	96	20 11 48	-20 1 45	1.825	-1 32	1 42.4	232,022
1906	Aug. 4	9:01:05.6 a.m.	9:00:12 a.m.	82	103	20 54 42	-17 22 17	1.786	+2 49.6	1 41.8	231,265
1924	Aug. 14	4:22:59.1 p.m.	4:20:06 p.m.	84	110	21 36 24	-14 9 3	1.659	+7 7.5	1 38.8	230,500
1942	Aug. 25	11:53:19.2 p.m.	11:48:00 p.m.	85	116	22 17 5	-10 28 35	1.541	+11 9.9	1 34.1	229,784



Three ways of observing the Ring nebula in Lyra, which is a typical planetary: direct photograph (upper left); slit spectrogram (upper right); and slitless spectrogram (bottom). All photographs in this article are from Lick Observatory.

"Ages of Observation"

By Lawrence H. Aller, *Harvard College Observatory*

Planetaries are pictured on our covers this month. Here is the story of what we know about them.

THE planetary nebulae were named by Sir William Herschel, who saw them in his telescope as faintly luminous, greenish disks. Their images were not unlike those of the outer planets and hence they were dubbed "planetary," although they have nothing to do with the planets of the solar system. The best known of the planetaries is the Ring nebula in Lyra, and a number of others are attractive objects for small telescopes. (See *The Telescope*, Sept.-Oct., 1940.)

Herschel, the first man to study the planetary nebulae, concluded that their uniform, shining disks could best be explained by supposing them to consist of some "condensed luminous fluid." Stars, he thought, could not produce the "soft tint" of their light. Later, it became fashionable to regard nebulae of all types as aggregations of stars, so distant that they could not be resolved into individuals. This opinion prevailed in 1864, when Huggins, examining the spectrum of the planetary in Draco (N.G.C. 6543), found it to consist of a few bright lines!

One of Kirchhoff's laws of spectroscopy, which were then very recent discoveries in physics, states that only a glowing gas of low density gives a spectrum of distinct bright lines. The sun and the other stars give continuous spectra crossed by dark lines. External galaxies and star clusters, which consist of great collections of stars, also have spectra of this type. But the diffuse, bright galactic nebulae, such as the Trifid in Sagittarius and the nebula in Orion's sword, show bright-line (emission) spectra, as do also the planetaries. Hence, they are gaseous and Herschel was right after all, although we would scarcely say that his luminous fluid is "condensed."

In direct photographs, planetaries show a great variety of forms. Some are ring-shaped; others appear as a ring superposed on a disk, for example, N.G.C. 7662; a number are quite irregular in appearance. The evidence is strong that all have a central star from which they derive the energy by which they shine.

The average planetary nebula is about 3,000 light-years away from us, has a radius of about 10,000 astronomical units (one A.U. is the distance from the earth to the sun), and a mass of probably about 1/10 that of the sun. Each planetary represents a higher vacuum than any we have produced on the earth—a tablespoonful of air expanded to the size of Pikes Peak would have about the same tenuity as one of these objects.

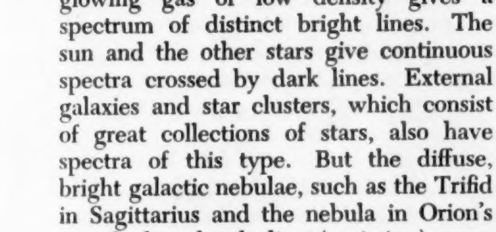


Fig. 1. The principle of the slitless spectrograph is shown here. The concave quartz lens renders parallel the rays of light from the primary mirror. They then pass through the quartz prism to a convex lens which focuses them on the photographic plate.

Our most interesting information about the planetaries comes from their spectra. The ordinary spectrograph, such as is used in studies of the stars, employs a slit to separate the various wave lengths, and is necessary in observing a planetary if we want to study the weakest radiations. But if we want to find out how the strongest radiations are distributed throughout the nebula, we should use a *slitless spectrograph*. Figure 1 shows the principle of this instrument, which is not to be confused with the *objective prism*. In the latter, the refracting prism is placed in front of the telescope's objective, and forms the spectrum of many objects *before* the light enters the telescope proper, whereas the converging rays from the primary lens or mirror of the telescope fall upon the concave quartz lens of the slitless spectrograph and one object is singled out for study.

The illustrations include slitless spectra of a number of objects. There is an image (line) for each principal wave length of the light emitted, but these differ in size and appearance. Familiar lines (images) of the well-known elements, hydrogen, helium, carbon, and oxygen, appear in the planetaries, but many of the strongest lines have never been produced on the earth. They were once attributed to a hypothetical element, "nebulium," a substance which was supposed to occur only in the gaseous nebulae and in novae or "new" stars.

In 1926, I. S. Bowen, of California Institute of Technology, exploded this myth by showing that the two strongest lines (at the extreme right in each spectrum—images run together) are due to oxygen atoms which had lost two of their outer electrons, that is, which are doubly ionized. However, these lines could be produced with great strength only in a gaseous medium of vast extent and very low density, so physicists could not observe them on the earth. All of the other mysterious strong lines in planetary nebulae arise from atoms of oxygen, nitrogen, and neon, shining under conditions impossible to duplicate on the earth. The identification of these so-called *forbidden lines* has been one of the triumphs of modern astrophysics.

In this problem, two characteristics of the spectral lines are of importance—their wave length and their intensities. W. H. Wright, of Lick Observatory, about 25 years ago made most careful and extensive measurements of the wave lengths of nebular lines for identification purposes. More recently, Bowen and the late A. B. Wyse extended these studies to fainter lines in three bright northern planetaries, N.G.C. 7662, 7027, and 6572. These measures have to be made with slit spectrograms, which give narrow lines whose positions can be ac-

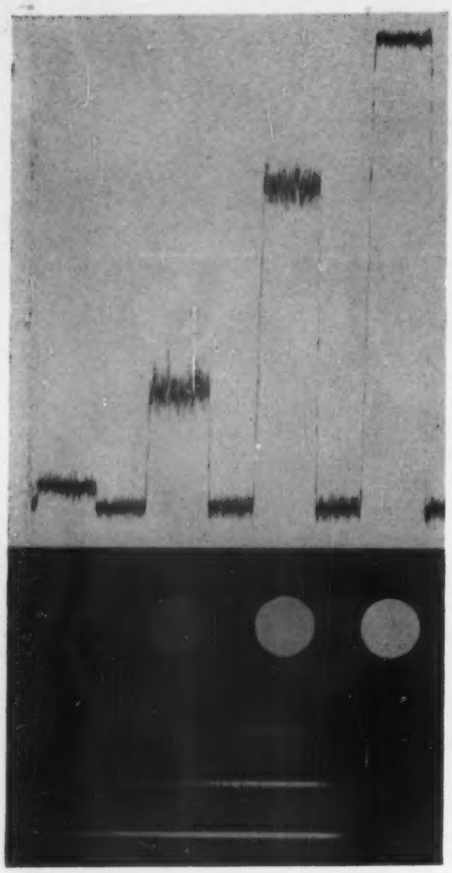


Fig. 2. Images on a photographic plate from a spot sensitometer. Spots are of intensity ratios 2, 4, 8, and 16. The microdensitometer tracings of similar spots are shown, together with three spectra of the comparison star, photographed with a diaphragm over the end of the telescope. The separate images differ in brightness by one magnitude.

curately obtained. The wave lengths of the unknown lines can be found only by comparing them to the positions of lines of known origin, for example, the usual hydrogen and helium lines.

In the illustration at the head of this article are shown the various ways of observing a planetary nebula. At the top is a direct photograph, and beside it a slit spectrogram, and finally, a slitless spectrogram.

The determination of spectral line intensities is a more involved and less accurate procedure than the measurement of wave lengths. Let us trace the steps involved.

What we want to know is the amount of radiation emitted by the nebula in each wave length represented by the spectral images. As everyone interested in photography knows, the blackening of the photographic plate (negative) depends on the quantity of light falling upon it. The brightest light in a scene gives the blackest, that is, the densest, images on the plate. However, the blackness is not simply proportional to the intensity of the light, but depends on it in a continuous but more complicated fashion.

To determine this relation, we may impress upon the plate a series of exposures of known relative intensities from some artificial light source. In the *spot sensitometer*, whereby this is accomplished, light from a lamp falls upon a diffusing opal glass. The light is then passed through a series of circular holes of different diameters and onto the photographic plate. Amounts of light of known values, ranging from greatest for the largest holes to least for the smallest, will produce spots ranging from blackest to weakest as shown in Figure 2. We can measure the density of each spot and construct at once a graph relating film density and light intensity.

By means of the *microdensitometer*, the density of the film of our spectrogram is automatically recorded. In this device, a small, intense beam of light passes through the photographic plate and onto a photoelectric cell which forms part of an electric circuit. When the density of the plate is low, much light will pass through, fall on the cell, and cause a large current to flow. This will cause a large deflection in a galvanometer which is also in the circuit and which carries a mirror reflecting light from a mercury-vapor lamp. At some distance from the mirror, so that considerable magnification of the galvanometer deflections is secured, is a revolving drum bearing photographic paper. As the mirror swings back and forth according to varying densities of the spectrogram (which is geared to the drum as it moves under the original beam) the spot of light reflected from the mercury-vapor lamp makes a permanent record of the density of a narrow strip of the spectrogram in the form of a *densitometer tracing*. Figure 2 shows the tracing of the spots made with the spot sensitometer. In practice, we have to make a number of adjacent tracings of any one planetary nebula, since the microdensitometer can measure but a narrow strip at a time.

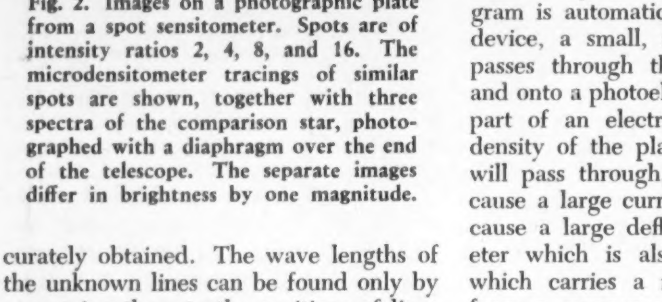


Fig. 3. The spectrum of a hot B3 star and the microdensitometer tracing thereof. The strongest lines are those of hydrogen and helium. The small wiggles are due to graininess of the plate. (This is a positive print of the spectrum — the tracing was made from a negative.)

Figure 3 shows the spectrum of a hot *B*3 star and its densitometer tracing. The top of the tracing corresponds to total blackness, the bottom, to clear film. In Figure 4 is a tracing of a narrow strip along the spectrum of N.G.C. 7662, and below this, the tracing reduced to an intensity scale by means of the curve in Figure 5. This curve relates light intensity to the deflections in the densitometer tracings.

The intensities shown in Figure 4 are not true intensities. The sensitivity of the plate for radiations of different wave lengths, the transparency of the earth's atmosphere and the optical systems employed, and the reflectivity of the telescope mirror, all affect the measured intensities.

We may get around these difficulties to some extent by using a comparison star whose true energy radiation has been measured or can be estimated from its spectral type. A comparison of this star's observed energy distribution (as computed from its densitometer tracing) with its true energy distribution enables us to correct our observations for the instrumental and other errors mentioned above. (See Figure 6.)

Notice in Table I, which shows, on a basis of $H\beta = 10$, the total intensities of the stronger lines in three planetaries,

TABLE I

λ	*N.G.C. 6543*	*N.G.C. 7009*	*N.G.C. 7662*
5007	60	96	156
4959	21	34	56
4861 ($H\beta$)	10	10	10
4686	—	1.4	5.3
4471	—	0.5	0.3
4363	4.1	1.0	2.2
4340	(4.1)	3.4	4.3
4101	2.1	2.5	2.6
3967	2.3	4.0	4.1
3868	5.3	9.9	11.4
3727	3.2	1.7	2.4

that the green nebular lines, 5007 and 4959, contribute most of the light of these objects. However, the oxygen atoms with two electrons missing which produce these lines are 1,000 or 10,000 times less abundant than the hydrogen atoms in these nebulae, where conditions are such as to favor production of the forbidden lines much more than of ordinary lines. This illustrates the danger of estimating the relative abundances of atoms from the intensities of the spectral lines they produce.

In estimating the abundances of elements, it is necessary to consider the manner in which their lines are produced. Forbidden lines derive their

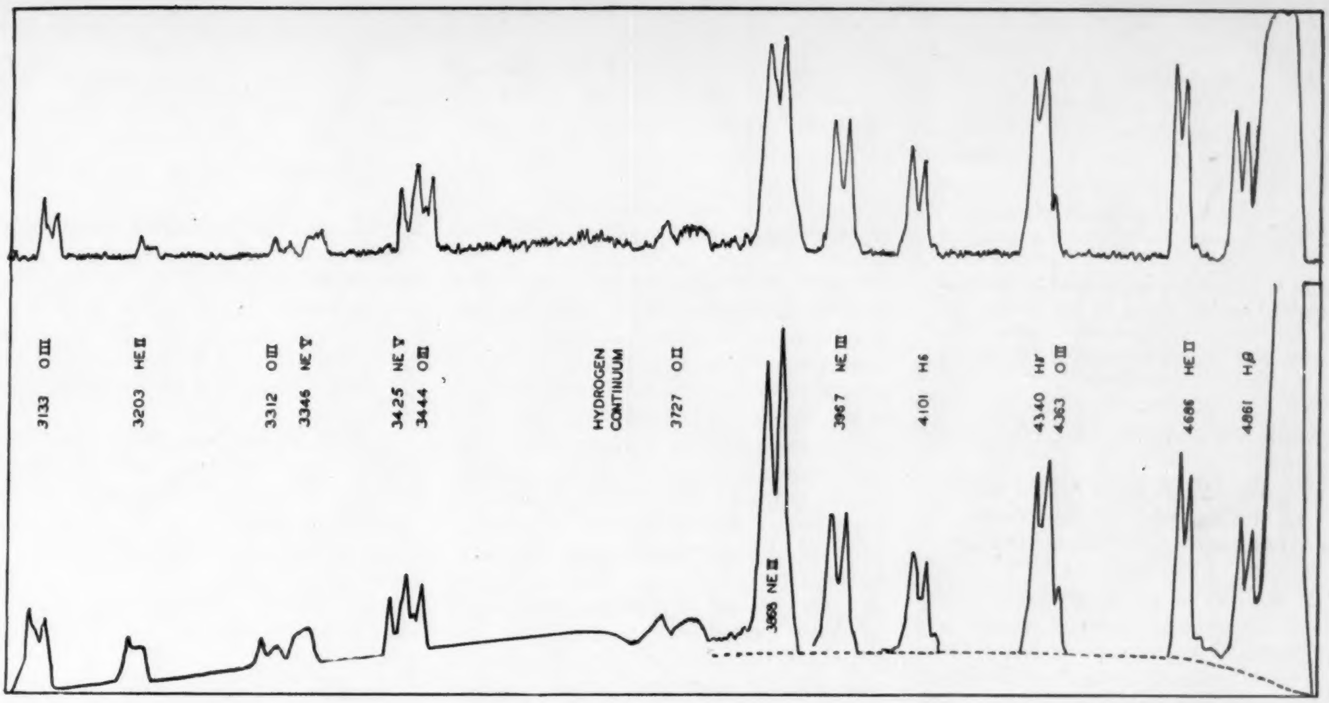


Fig. 4. The tracing of a narrow strip along the spectrum of N.G.C. 7662 (on top). The lower curve is the tracing corrected to a relative intensity scale by means of the curve in Figure 5. Compare each line (image) with its tracing, both as to shape and height.

energy from the impacts of electrons, which collide with the atoms and excite them to energy states from which they can return to normal only with the emission of forbidden lines. The lines of hydrogen originate in another way as far as planetaries go. A hydrogen atom absorbs light of great energy (short wave length=ultraviolet) so that it becomes ionized by losing an electron. Then another electron is captured in place of the first, and it may land in a position in the atom corresponding to a high-energy state. As the electron "cascades" downward to lower energy states, the atom may emit the usual permitted lines of the hydrogen Balmer series.

As in all scientific problems, the finding and allowing for errors of a systematic nature is important in studying planetary nebulae. There are five important errors:

1. The density-intensity relation depends on the wave length of the light. An attempt is made to allow for this by using different color filters in the sensitometer, and also by photographing the comparison star with diaphragms over the end of the telescope. (See Figure 2.)

2. The transmission of the atmosphere, especially in the ultraviolet, is variable.

3. The assumed energy distribution of the comparison star may be in error.

4. The absorption of light in space

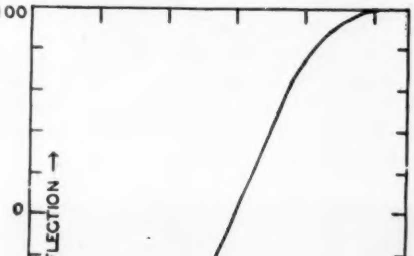
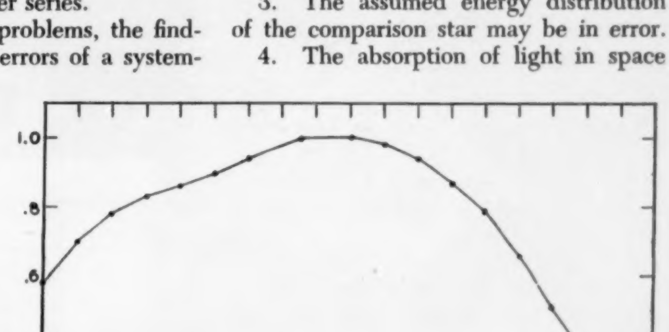


Fig. 5. By means of this curve, the deflection of the microdensitometer galvanometer (height on tracing) can be corrected to true relative intensities.

Fig. 6 (right). Relation between plate-plus-instrument sensitivity and wave length for an Eastman 33 plate. The intensities of the lower curve in Figure 4 are to be divided by ordinates read from such a curve as this, and the results are true relative line intensities. Thus for the Hβ line, 4861, we read 0.30 from the curve, so the observed Hβ must be multiplied by 1/0.30, or 3.3. However, for Hδ, 4100, we read 1.00 from the curve, so there is no correction.



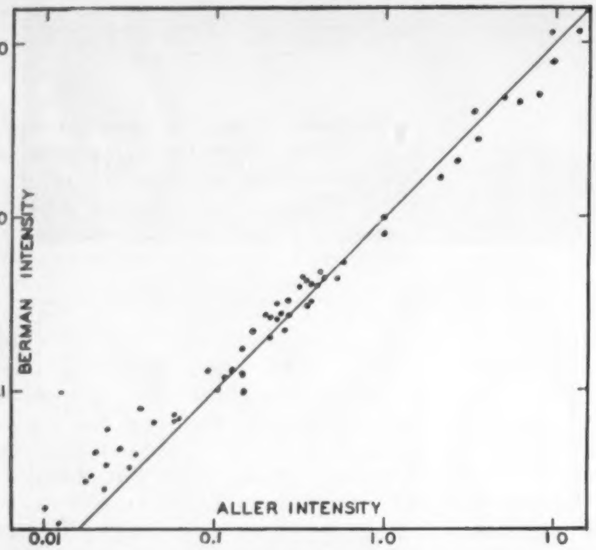


Fig. 7. Intensities determined by Berman plotted against those by the author, on a non-uniform (logarithmic) scale. The solid line represents results in perfect agreement.

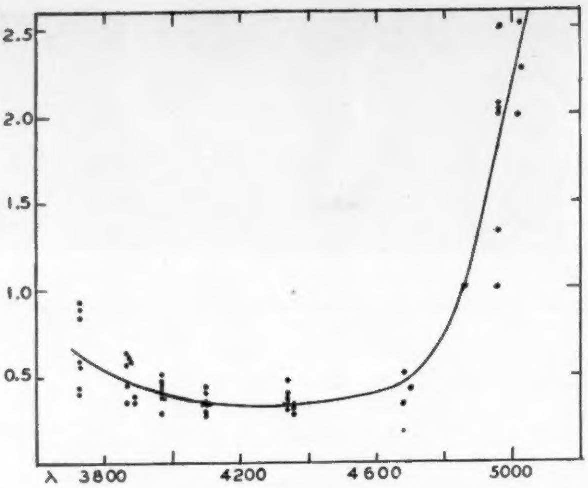


Fig. 8.

between us and the planetary is unknown.

5. We do not know where to draw in the background of the continuous spectrum in the densitometer tracings.

An idea of the effects of 1, 2, 3, and 5, as well as of errors made in simply measuring tracings, may be obtained by comparing the measures of Dr. L. Berman with those of the author, as shown in Figure 7. For the most part, the errors are not large, but the weaker spectral lines show systematic differences, arising from 5. The agreement of intensities is good, considering the difficulties involved. Berman used the same instruments, the quartz slitless spectrograph and the Crossley reflector of the Lick Observatory, but his comparison star and methods of reduction were different from mine.

In his work 25 years ago, at a time when modern photometric techniques were not available, Wright also estimated the intensities of the bright lines in a large number of planetaries, but he was unable to correct his results for the effect of plate sensitivity. However, by a comparison of intensities measured in objects common to Wright's and the author's lists, the former's estimates can be reduced to a more nearly true relative intensity scale, as shown in Figure 8. This comparison enables us to have intensity estimates for a much larger number of planetaries than have been observed photometrically.

As in the case of wave-length measures of weak lines, the intensities of these lines can best be measured on slit spectrograms of long exposure. But a slit is wasteful of all the light except that which passes through its very narrow opening. Recently, Bowen and Wyse opened a new era in the spectroscopy of planetary nebulae by using the former's invention called the "image-slicer." This device interrupts the light from the telescope's objective, cuts the image up into little strips by a series of mirrors, and reflects these into the slit so that no light is lost on the jaws of the slit.

Bowen and Wyse were therefore able to photograph many new lines, establishing the presence of a number of elements previously unknown in the planetaries. Most of the atoms observed show forbidden lines, although helium, hydrogen, carbon, and oxygen are represented by their permitted lines. In his last paper, Wyse reported on 10 gaseous nebulae. He confirmed that their chemical compositions are probably all about the same as or similar to that of the sun, a conclusion reached by Bowen and himself from their previous work.

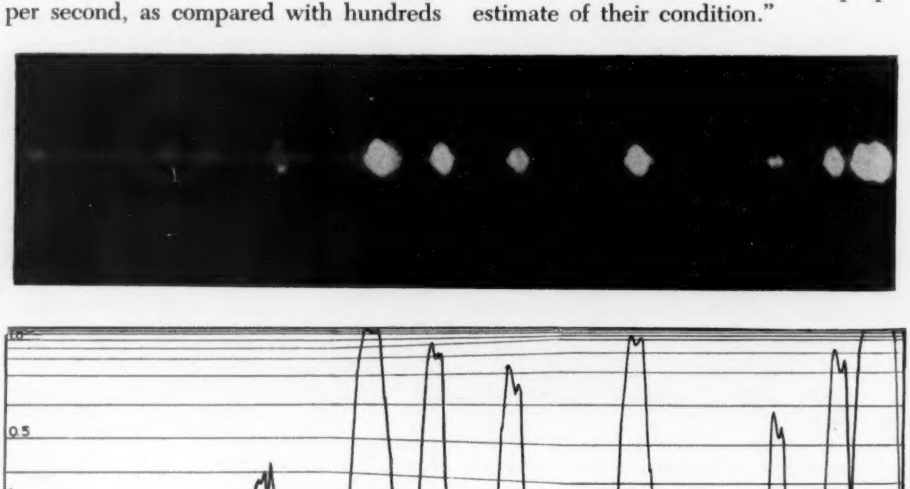
As to the origin of the planetary nebulae, we can say but little. Gaseous shells, similar in nature to planetaries, but expanding at a very great rate, have been seen around certain novae, but these shells prove to be very temporary affairs. The rates of expansion of the planetary nebulae, as observed by Campbell and Moore, are 10 or 20 kilometers per second, as compared with hundreds of kilometers per second for novae shells. If planetaries originate from novae, it must be from very "slow" ones, such as RT Serpentis. But they do seem to be slowly expanding, and in the course of 20 or 30 thousand years (according to Dr. F. L. Whipple) they will dissipate into space.

Little is known about the central stars of planetaries, which appear to be dwarfish stars of extremely high temperature (20,000 degrees Kelvin to 100,000 degrees Kelvin), but nothing is known of these stars' masses. They show spectra of the Wolf-Rayet type—broad bright lines superposed on a continuous spectrum.

Because they are probably among the most remote of galactic objects, the distances of the planetaries are relatively inaccurately known. There is opportunity for good work in measuring their true brightnesses. Further spectroscopic studies, especially in the infrared, are desirable.

In closing, we may recall the words of Sir William Herschel:

"The nature of these objects is enveloped in much obscurity. It will probably require ages of observation before we can be enabled to form a proper estimate of their condition."



A slitless spectrogram and microphotometer tracing of N.G.C. 7009.

BEGINNER'S PAGE

By Percy W. Witherell

Meteors—and the Perseids

METEORS, the general name for "shooting stars" (beloved by the romantic), the meteorite (of interest to the geologist and astronomer), and the fireball (believed of dire portent by the credulous), have attracted the attention of mankind even before the dawn of history.

The Perseids which appear in August every year are "regular troopers" who have not missed their cue since 1762. As the moon is new on August 11th this year, a careful watch of the sky for a few days before and after August 12th should reward the observer, if Nature co-operates by providing some cloudless nights. The most favorable time to see the maximum number of meteors per hour is after midnight, and this applies also to showers such as the Perseids. A meteor can be identified as a Perseid if its line of flight extended backward passes near the constellation Perseus. The divergence of the trails of shower meteors from one *radiant* point really is an effect of perspective, as their paths in space are parallel.

Observers on our coasts might relieve the tedium of their duty watching for planes by counting the number of meteors they see in a half hour, and keeping an accurate record of the time of the beginning and ending of each such period. As a constant watch has probably instilled some knowledge of the constellations, it would also be interesting to note bright meteors, especially the relation of their beginning and end points to bright stars, and to plot the meteor paths on a star chart. A ruler or pencil held in line with the path will help to locate it after the light of the meteor has faded. If a fireball should appear, note any fluctuations or explosions. The above data, with the location of the observer, will be welcomed by Harvard College Observatory or the American Meteor Society, Flower Observatory, Upper Darby, Pa.

The average meteor is about the size of a nut and becomes visible when the friction of the air heats it to incandescence. Meteors first appear about 60 to 80 miles above the surface of the earth and usually burn themselves out in a fraction of a minute. The large ones naturally take longer to be consumed and so disappear at lower altitudes. Sometimes they reach the surface of the earth and are called meteorites. The very brilliant ones, which move slower, often leaving radiant trails, and sometimes exploding, are named fireballs.

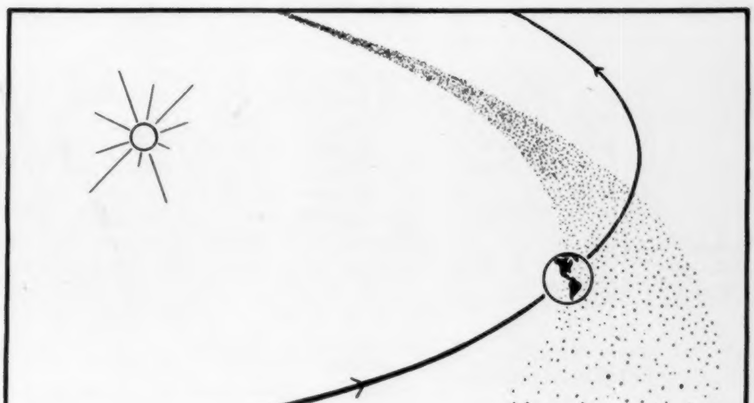
Do any meteorites come from interstellar space? For years, visual observations seemed to show that many meteors had very high speeds that indicated their origin to be outside the solar system. More careful photographic observations of the last few years have failed to confirm these high velocities. At present, there is no satisfactory evidence of the appearance in the solar system of any object from interstellar space.

Comparisons of the orbits of many meteor showers with those of several well-known comets have shown striking similarities and indicate that meteor streams are debris from the disintegration of comets. When the earth in its journey around the sun passes through one of these orbits, meteors appear in varying numbers according to the density of the stream at the point of intersection. The disappointing non-appearance of the Leonids in November, 1899, after their astounding displays of 1833 and 1866, was due probably to a permanent displacement of their orbit by Jupiter's gravitational influence. The orbit of the Perseids is nearly perpendicular to that of the earth and is therefore not subject to serious planetary disturbances; consequently, this shower is very satisfactory and punctual each year.

In answer to the questions of K. A. of New York, the above remarks may be supplemented by stating that while there is no evidence of the appearance of a comet or asteroid from interstellar space, it is possible that the orbit of a comet might be perturbed so that it could leave the solar system never to return.

Photographic studies made by synchronized cameras at present record only the bright fireballs, which are apt to be of lesser speed than the faint meteors. Radio communication has made possible identification of faint meteors observed simultaneously from different stations, so their heights and actual speeds can be calculated. In coming years, such investigations may produce positive rather than negative evidence that such objects are of interstellar origin. Needless to say, the analysis of any specimen of known origin outside the solar system would be of greatest interest.

Right. A fireball is caught by the camera. Note the changes in the meteor's brightness.



The earth cuts through a swarm of meteors.

NEWS NOTES

By Dorrit Hoffleit

ON THE BIRTH OF PLANETS

The oft-discussed problem of the inhabitability of the rest of the universe appears to remain the average layman's favorite astronomical interest. *Science* for June 12th has published a lecture on this topic delivered by Sir James Jeans to the Royal Institute of Great Britain. On the perhaps dubious assumption that planets are born as the result of a close encounter of two stars, he finds that a given star would become parent to a planetary family about once every million million million years. If we suppose that the average age of a star is 2,000 million years, then at most one star in every 500 million will now have a planetary system.

Although this is a minute fraction of the stellar population, it indicates that in the entire universe about two million million stars may already be surrounded by planets and that a new system is born every few hours. Of course, most of these "planets" will be as uninhabitable as our brethren between Mercury and Pluto. But in so large a total, an appreciable number are likely to have physical conditions similar to those prevalent on earth. In regard to inhabitants, Jeans says:

"We can only wonder whether any life there may be elsewhere in the universe has succeeded in managing its affairs better than we have done in recent years."

THE SOLAR CORONA

For many years the origin of numerous lines appearing in the spectrum of the solar corona could not be explained. Last year the astrophysicists, Grotrian and Edlén, succeeded in showing that the chemical elements responsible for the mysterious lines are just common ones like iron and nickel, but whose atoms were stripped of a large number of their planetary electrons. Thus iron, which normally has 26 electrons, was found to be robbed of 13. In a note to *Nature*, M. N. Saha, of the University College of Science, Calcutta, remarks that the difficulties previously experienced in working out the physical theory of the solar corona have apparently been increased by this discovery. Nevertheless, Saha has worked out a theory, to be published shortly in India. He believes that the only plausible hypothesis for the existence of these highly stripped atoms is that they are produced in a nuclear reaction, analogous to uranium fission, occurring somewhere beneath the reversing layer of the sun.

The second lightest element, helium, was discovered in the sun, but not in the normal spectrum produced in the reversing layer. The anomaly of the presence of the ionized helium line 4686 in the spectrum of the lower chromosphere, and of neutral helium in the upper chromosphere, has long been an unexplained puzzle. For this case, Saha believes that some kind of nuclear reaction which gives rise to alpha-particles (helium nuclei) is responsible. An alpha-particle, in its passage through the solar envelope, first captures an electron, thus becoming a singly ionized helium atom; then it captures another electron and becomes an ordinary helium atom. The outer corona is believed to consist almost entirely of electrons, but it was difficult to trace their origin. Perhaps they are the so-called delta-rays expelled from the solar atoms by the highly ionized iron or nickel atoms in the upper chromosphere.

THE REV. T. E. R. PHILLIPS

We regret to announce the death on May 13th of the Rev. Theodore Evelyn Reece Phillips, at the age of 74. He had been rector of Headley, Epsom, and past president of the Royal Astronomical Society and the British Astronomical Association. (See *Sky and Telescope*, "News Notes," May, 1942.)

DR. WRIGHT RETIRES

Dr. William Hammond Wright, director of the Lick Observatory since 1935, retires this year after 45 years of service to that institution. A native Californian, he did his undergraduate work at the University of California and graduate work both there and at Chicago. His investigations have included novae, nebulae, planetary photography, and especially stellar motions. Dr. Wright has been the recipient of many medals, and in 1929 was awarded a Sc.D. degree by Northwestern University. Dr. Wright is to be succeeded as director by Dr. Joseph Haines Moore, who has been associated with the Lick Observatory since 1903 and been assistant director since 1936.

THE ADOLPH LOMB MEDAL

At the annual meeting of the Optical Society of America in October, the Adolph Lomb medal for 1942 is to be presented to Dr. James G. Baker, research fellow at the Harvard College Observatory. The medal is awarded biennially for noteworthy contribution to optics. Dr. Baker's work in geometrical optics and lens design has proved important in the development of new types of astronomical instruments.

NOT NEWS; NEWLY IMPORTANT

Astronomers working at night have always found red light more satisfactory than any other. A red light turned on suddenly, but just long enough for an observation to be recorded, does not leave an afterimage that is apt to interfere with the next observation, as a white or blue light would. Astronomers likewise have been aware of the difference between "night-eyes" and "day-eyes." The retina of the eye is made up of so-called rods and cones. In bright illumination it is the cones that function—they are the important feature of your day-eyes. The rods are active only when the illumination is very low, and are hence the principal functionary of your night-eyes—which, incidently, are color-blind. Also there is a blind spot at the center of vision of night-eyes; in a telescope you may get perfect definition at the edge of the field while there is an annoying dark spot at the center. Count the Pleiades some dark night. If you can see more of them out of the corner of your eye than when you are looking straight at them, then you know that your day-eyes have turned over the keys of vision to your night-eyes.

This is old news that has recently acquired new importance. Good night-eyes are essential for airplane spotters, pilots, lookouts, wardens, and many others. But your eyes have to become trained and they have to be given consideration. Ordinarily it takes a person coming out of a well-lighted room half an hour to acquire keen night vision. Once accustomed to the dark, his night vision may be destroyed for another half hour if a white light is flashed on for only an instant. Red light affects the rods of the eyes less; that is why astronomers, air-raid wardens, and others who have to see in the dark prefer it. Red is better, too, says Science Service, since enemy planes will detect it less readily. The Navy's new Night Vision Board warns: blue light is the worst possible during blackouts.

TARDY MERCURY HURRIED

In the summer of 1940, the U. S. Naval Observatory issued a general request for observations of the transit of Mercury which was to take place on November 11-12th of that year. Nearly 200 observers, many of them amateurs, distributed between terrestrial longitudes 175° E. and 157° W., responded. The results of their observations are discussed by G. M. Clemence and G. C. Whittaker in a recent *Publication* of the U. S. Naval Observatory. They find that the transit happened 36 seconds later than expected and lasted 18 seconds less. The tardiness is assumed to be caused by irregularities in the rotation of the earth, which lead to errors in the reckoning of astronomical time. The accuracy of the observed time deviation in this instance could be checked by observations of the moon, which yielded a value of the "fluctuation" of 35.3 seconds, in good agreement with the Mercury transit value.

The shortness of the duration of the transit is not wholly accounted for. Observational difficulties may readily account for part of Mercury's apparent haste, but the discordance between observation and theory is too large to be entirely attributed to this cause.

DO YOU KNOW?

By L. J. Lafleur

MOON QUIZ

I. Score four points for each question answered correctly, and one point for each question where you do not attempt to select the answer.

1. The lunar terminator is the
   a. day preceding new moon
   b. boundary between light and dark portions
   c. first sunlight on the moon after a total lunar eclipse
   d. edge of the visible hemisphere
2. In temperate latitudes, after sunset in the spring, the line joining the tips of the horns of the crescent moon is seen
   a. nearly vertical b. nearly horizontal
   c. pointing due north d. curved
3. Terrestrial tidal friction caused by the moon is making the
   a. day and month longer
   b. day and month shorter
   c. day longer and month shorter
   d. day shorter and month longer
4. The full moon looks like a peeled orange because of rays extending from the lunar crater
   a. Copernicus b. Theophilus
   c. Tycho d. Kepler
5. We know more than half of the moon's surface. Which of these is not a reason for this?
   a. The earth is larger than the moon.
   b. The moon's rotation and revolution are equal.
   c. The moon's orbit is elliptical.
   d. The moon's axis is not perpendicular to its orbit.
6. The visibility of the dark portion of a "new" crescent moon is due to
   a. earthshine b. refraction
   c. phosphorescence d. starlight
7. The moon, compared to other satellites, is
   a. smaller than the average
   b. of average size
   c. smaller in proportion to its primary
   d. larger in proportion to its primary
8. As far as we know now, tidal friction is causing the moon to
   a. recede from the earth
   b. approach the earth
   c. first recede and then approach
   d. first approach and then recede
9. The moon appears largest at
   a. apogee b. perigee c. syzygy d. a node
10. Because of the scarcity of air, an observer on the moon would not notice
    a. sharp shadows
    b. the sun's corona
    c. hollow quality of sounds
    d. extremes of temperature

II. Pair the figures in the first column with the terms in the second. Count three points for each correct pair.

.0123	albedo
.0549	density[1]
.073	diameter
.16	eccentricity
1.5	mass[2]
3.34	nutation[3]
18.6	precession[3]
27.32	revolution
2,160	surface gravity[2]
25,800	velocity of escape

[1]Water = 1 [2]Earth = 1 [3]Years

III Can you locate on the accompanying photograph the following 10 lunar features? Count three points for each correct identification.

1. Alps	6. Mare Crisium
2. Apennines	7. Mare Imbrium
3. Archimedes	8. Mare Tranquilitatis
4. Aristotle	9. Plato
5. Copernicus	10. Ptolemy

(Answers on page 20)

AMERICAN ASTRONOMERS REPORT

(Continued from page 9)

fraction. This is so as to tell the ratio of the intensities of two stars, and hence their difference in magnitude. A possible method is to place in the beam a small disk from which a sector has been cut away. If the disk is set rotating during the exposure, the star's light is reduced in the ratio of the open part of the disk to the solid part.

Here however, we run into a snag brought about by that familiar foible of the photographic plate known as *reciprocity failure*. The emulsion does not react in the way it would to a constant light of the reduced intensity. Instead, a more intense image results. Work in the laboratory has indicated, however, that if one takes care to spin the sector fast enough, such serious error is likely to be avoided. The purpose of this paper was to show that for light of astronomical intensities, if the disk rotates more than about 4,000 times per hour, the plate will be successfully "hoodwinked" and will react as it should. The so-called "magnitude scale" set up by this new method will contain no systematic errors.

THE application of a rotating sector in another field, positional astronomy, was the subject of a paper by L. F. Barcus, of the Sproul Observatory. The relative positions of two stars may be much more accurately measured photographically if they are of nearly the same brightness. This is rarely the case, and sectors are generally used to reduce the brighter star. Mr. Barcus described the difficult job of cutting and mounting a set of sectors giving reduction factors from a few tenths to several magnitudes.

GLEANINGS FOR A. T. M.s

EDITED BY EARLE B. BROWN

DESIGNING AN ACHROMATIC OBJECTIVE

The ambitious amateur will sooner or later want to make an achromatic objective, and those with a flair for mathematics will want to design their own. We accordingly begin this series, outlining a method for designing an achromatic objective, and shall attempt to make the principles clear enough so that the reader can apply them to an objective of any optical dimensions. Because there are some amateurs who will not be interested in this series, its installments will be printed bimonthly.

ALL amateur telescope makers who have consulted literature on the subject of the achromatic lens have found certain recommended curvature ratios, and perhaps simplified formulae for corrected objectives. It is true that approximate formulae can be derived which will yield reasonably good objectives so long as the field is restricted and the focal length is kept long.

But the use of these formulae does not give the user any understanding of the principles of lens design, nor is it possible for him to know in advance just how good the corrections of his lens can be expected to be. The only way in which an objective can be properly designed is by detailed trigonometrical ray-tracing. Our problem will be, therefore, first to develop equations for ray-tracing, then to apply these equations in the designing of a sample achromatic objective to give certain desired corrections. Since the "sixth sense" and accumulated experience of a professional designer will not be available to the reader when he goes to work on his own design, no attempt will be made here to take advantage of them, nor will we take time to develop or use any of the numerous short cuts the professional would draw upon; we will "muddle through" with kindergarten methods. In this way, our job will be much longer, but it will make the underlying principles clearer, and that, after all, is our prime purpose.

1. The Fundamental Equations. Ray-tracing is a simple geometrical problem. We are given the law of refraction (Snell's law). and application of this law to a known ray at a known surface determines the path of that ray after passing the surface. This is all we need to know, and this knowledge, for a few selected rays, determines the optical properties of the surface.

For the purpose of ray-tracing, light is considered as composed of rays, with the properties of geometrical lines. We state, without demonstration, that this assumption is valid for our purposes. *We are not concerned with the physical nature of light*—only with its geometrical properties.

Consider Figure 1. This is the customary illustration of the phenomenon of refraction.

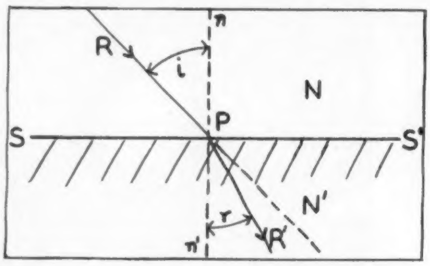


Fig. 1. Refraction at a surface.

N and N' are two media, of refractive indices N and N', respectively. They meet at the surface SS', with the normal (perpendicular) nn' at P. The incident ray, R, is at angle i with the normal at P, and the refracted ray, R', makes the angle r with this normal. The law of refraction states:

$$N \sin i = N' \sin r,$$

and since, in the diagram, sin i is obviously greater than sin r, N' must be greater than N, or, as we say, N' is the *denser* medium. The refractive index of a medium, such as optical glass, is given in tables, or measured with a spectrometer or refractometer. It varies for different wave lengths (colors) of light. The refractive index of air is 1.00001, and we take it to be 1 exactly, for convenience.

It is with curved refracting surfaces, however, that we shall be chiefly concerned. These curves are spherical (except in unusual cases which we shall not consider) with centers all lying on one line, the *optical axis* of the system. In other words, we shall be dealing only with *centered* optical systems with spherical surfaces.

In Figure 2, SPAS' is a surface in an optical system with optical axis XAX'. DPC is the normal to the surface at P, and PC is its radius of curvature. An incident ray, RPB, meets the surface at P, and is refracted to follow the path PB'. The refractive indices of the media to the left and to the right of the surface are N and N', respectively. In this case, N' is greater

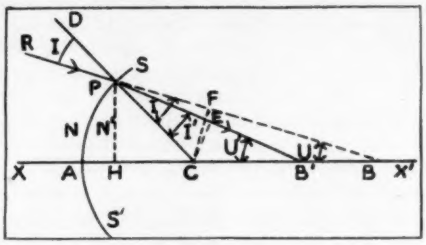


Fig. 2. Geometrical construction at a refracting surface.

than N, hence the ray is bent *toward* the normal.

The data we wish to obtain are: the intersection-length AB', the angle U' between the refracted ray and the optical axis, and the angle I' between the normal and the refracted rays. Any two of these quantities define the third, hence we will confine ourselves to computing for AB' and U'. The corresponding initial data for the entering ray are AB, U, and I, of which we may assume we know AB and U. Since any optical system will consist of a succession of surfaces, we will need a computation for each, and the resulting AB' and U' of each surface will give us the initial AB and U for the next surface.

Suppose, then, we are given, N, N', PC, AB, and U. We wish to find AB' and U'. Now

$$AB' = AC + CB' = PC + CB';\ CB' = \frac{EC}{\sin U'};$$

$$EC = PC \sin I';\ \text{so } AB' = PC + \frac{PC \sin I'}{\sin U'} \qquad (a)$$

$$\sin I' = \frac{N}{N'} \sin I \ \text{(law of refraction)} \qquad (b)$$

$$U' = U + I - I' \qquad (c)$$

$$FC = (AB - AC) \sin U = (AB - PC) \sin U$$

$$\sin I = \frac{FC}{PC} = \frac{(AB - PC) \sin U}{PC} \qquad (d)$$

Symbols. It is desirable that we adopt standard symbols for our various quantities:

a. We trace always *from left to right.*
b. "Primed" quantities indicate data *after refraction*, plain quantities, data *before refraction.*
c. The radius of curvature is denoted by **r.**
d. The angle between ray and axis is denoted by **U.**
e. The angle between normal and ray is denoted by **I.**

f. The refractive index is denoted by N.
g. The intersection-length (from pole of surface to intersection of ray with the optical axis) is denoted by L.

Figure 2 is redrawn to show the quantities labeled according to the above plan (Figure 2a), and we have: $PC = AC = r$; $AB = L$;

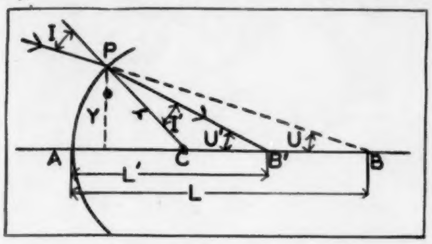


Fig. 2a. Final-formula lettering.

$AB' = L'$; and other quantities remain as previously labeled.

We can now rewrite equations (a) and (d) as follows:

$$L' = r + \frac{r \sin I'}{\sin U'} \quad \text{(a);}$$

$$\sin I = \frac{(L - r) \sin U}{r} \quad \text{(d).}$$

Our computation is simplified if we divide (a) into two equations, and write all of them in the following order:

$$\sin I = \frac{(L - r) \sin U}{r} \qquad (1)$$

$$\sin I' = \frac{N}{N'} \sin I \qquad (2)$$

$$U' = U + I - I' \qquad (3)$$

$$L' - r = \frac{r \sin I'}{\sin U'} \qquad (4)$$

$$L' = (L' - r) + r \qquad (5)$$

These are the five fundamental equations which will form the basis of all our computations, which will be made with logarithms. It will be found that this arrangement of the equations is convenient; it is easier to add and subtract the angles themselves in equation (3) than to attempt to deal with the trigonometric functions directly.

NEW BOOKS RECEIVED

WEATHER ELEMENTS, *Thomas A. Blair*, 1942. Prentice-Hall, Inc., 401 pp. $5.00 trade; $4.00 school.

A revised edition of a text first published five years ago presents an introduction to modern meteorology. Problems appear at the end of each chapter, and the bibliography will aid the layman in further study.

BOOKS AND THE SKY

ESSENTIALS OF ASTRONOMY

JOHN CHARLES DUNCAN. Harper and Brothers, 1942. 179 pages. $1.85.

THIS short text, of seven chapters and 14 appendices, by a well-known teacher of astronomy, is unique in many respects. It is in no sense a condensation of the more comprehensive text by the same author, but rather a book written especially for those shorter courses in astronomy for which standard texts contain far too much material.

In *Essentials of Astronomy*, Prof. Duncan has made a contribution toward a new method of presenting the subject matter of astronomy to elementary students. Chapter 1, "The Appearance of the Sky," is divided essentially into five parts—watching the sky all night, watching for a month, for a year, for a lifetime, and for a period of years. An attempt is made first to orient the student by describing the apparent movements of the celestial bodies, which form the basis of the science, in the manner in which one would naturally proceed if he were making the observations himself for the first time. Since few students have ever made systematic observations of any kind, the material outlined in this chapter must be carefully developed by the teacher lest the student become entangled with confused and hazy notions. This is especially true in view of the great number of new ideas and terms which are only briefly mentioned in the text. For instance, two sentences are devoted to proper motion (which is developed, however, more fully in the last chapter).

In Chapter 2, "Appearances Interpreted," the student is shown how the scientific method of thought is applied in correlating and interpreting the observations in Chapter 1. The interpretations which are advanced by way of explanation of the apparent movements of sun, planets, and stars, lead smoothly to the comprehensive laws of Newtonian mechanics described in Chapter 3, "Gravitation." The method of approach used in these chapters should give to the thoughtful student an appreciation not only of the factual side of astronomy, but also some idea of the human endeavor which has brought the science to its present high status among intellectual activities.

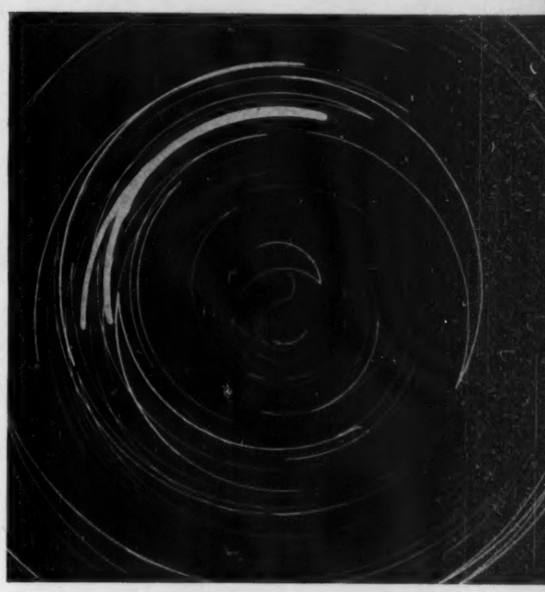
Chapter 4, "Light," includes a discussion of the basic properties of radiation and the construction and use of optical instruments of special interest to astronomers. The diagrams are many and well chosen.

The remaining three chapters carry the reader rapidly through the solar system and allow a brief visit to the sun, a few glimpses at some interesting stars, a fleeting look at clusters and diffuse nebulae, and then into outer space. It is trivial to go into minutia concerning what might have been included in these chapters. Suffice it to say that the delightful style of writing and the material which was included made the reviewer wish that twice as much had been written. Let us hope that the student will feel inclined to continue his study after reading this book.

The extreme brevity of the material on astrophysical subjects should enhance the usefulness of the book for pre-aviation training courses during the present war.

A review of this book would not be complete without mention of the frontispiece—a Kodachrome of the Orion region reproduced by four-color process. While there is little reason to doubt that direct color photography will find many uses in elementary astronomy, one must be extremely cautious regarding the interpretation of such photographs. The present picture depicts the bright stars with reasonable faithfulness. Stars of lesser brilliance appear in yellow, and very faint ones, blue. Here and there are green stars! At first glance, one might be tempted to regard the very numerous yellow stars as cool, late spectral-type stars. Such a conclusion would be quite erroneous, since, for the most part, they are *B* and *A* stars. The difficulty arises from the fact that color films fail to give faithful color reproduction if the overall light-intensity range is very great. This must inevitably be the case in an exposure of a star field.

R. WILLIAM SHAW
Cornell University



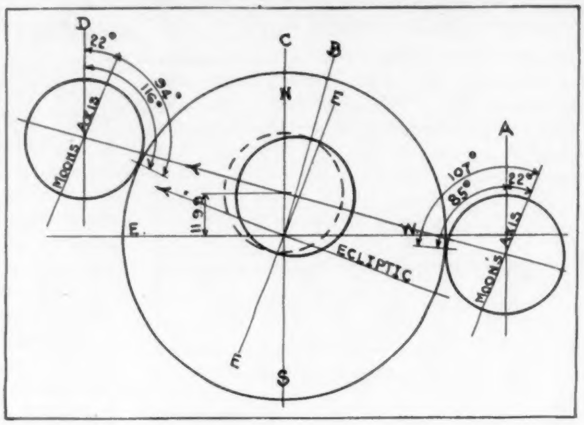
An engraving from "Essentials of Astronomy" which shows the effect of precession on the position of the pole. Circumpolar star trails taken in 1907 and 1941 are superimposed.

OBSERVER'S PAGE

By Jesse A. Fitzpatrick

All times mentioned on the Observer's Page are Eastern War Time.

The Eclipse of the Moon—August 25-26, 1942



Observe that the moon's path is inclined about five degrees to the ecliptic, the path of the umbra of the earth's shadow (large circle). A table of data on this eclipse and others in its saros is on page 10.

FOR the benefit of the amateur who is not conversant with the terminology associated with eclipses, I have made a drawing to show the principal features of the dark part of the eclipse of August 25th, and will endeavor to explain what is happening in the sky at the time. The large circle represents the umbra or dark shadow which is constantly cast into space by the earth intercepting the light from the sun. The small circles show the moon's passage through the umbra.

For this particular eclipse, the diameter of the umbra is about 5,800 miles. We do not know its exact diameter because of the varying density of the earth's atmosphere. It is customary to add from 30 to 70 miles to the computed diameter to allow for this uncertain factor, and that is why the actual times for lunar eclipses may vary as much as 15 or 20 seconds from the computed times. This is not the case in solar eclipses, because the moon, which then casts the shadow, has no atmosphere. As the earth revolves around the sun, the umbra is always projecting into space, and the imaginary line described on the celestial sphere by its center is the ecliptic.

A second shadow, called the penumbra, averaging about 10,000 miles in diameter, surrounds the umbra, but is so faint that its visible effect is only to cause a slight dimming of the moon's glare. It is possible for the moon to pass above or below the umbra and still remain wholly within the penumbra. This is called a penumbral eclipse, or *appulse,* and at the middle of such an eclipse the bright "rays" emanating from the craters, Tycho, Copernicus, and Kepler, disappear.

As indicated by the arrows on the drawing, the umbra and the moon are both moving in an easterly direction. During this particular eclipse, the moon's path is at an angle of 15° 28′ 14″ north of due east and the moon is moving about 15 times as fast as the umbra, whose direction lies 20° 41′ 36″ north of east. The position angle of the moon's axis being 338°, the moon's north pole will be 22° west of true north.

At position A, the fast-moving moon will catch up with the slow-moving umbra and make the first contact 85° east of north. This point is about 7° south of the southern end of the crater, Grimaldi, a distance slightly less than the length of the crater itself. The moon's libration in longitude being within three days of maximum positive, Grimaldi, known as the blackest spot on the moon, will be very near the eastern edge of the disk. This contact will occur at 10:00 p.m.

At position D, the moon has completed its passage through the umbra, the last point of contact being 116° west of the true north point of the moon, very close to the northern edge of the crater, Kastner. This contact will happen at 1:35 a.m., August 26th.

As the moon passes through the umbra, its center meets the north-south axis of the latter, as shown at C. This is called *conjunction in right ascension,* and will occur at 11:53:19.2 p.m., as noted in the table on page 10. At that moment, the moon's center will be 11′ 9.9″ north of the center of the umbra. A few minutes earlier, at 11:48 p.m., the center of the moon will meet a line perpendicular to its path and passing through the center of the umbra, as shown at position B. This is the *middle of the eclipse.*

Still earlier, the center of the moon meets a line perpendicular to the ecliptic and passing through the center of the umbra. This is shown on the drawing as E-E and is the *position of full moon.* Elsewhere on the "Observer's Page" this is noted as happening at 11:46 p.m. To avoid confusion, I have not drawn a circle representing the moon in this position.

The magnitude of the eclipse is measured at the instant when the moon is most deeply immersed in the umbra, and occurs at position E-E. It is the distance along the line E-E from the upper edge of the umbra to the lower edge of the moon divided by the latter's diameter. In this eclipse, the diameter of the umbra, including the allowance for the earth's atmosphere, is 5,860 miles. At position E-E, the moon's center is 10′ 26.7″ from the center of the umbra, equivalent to 682 miles based on the moon's distance from the earth at this time, 229,784 miles. Since the moon's semidiameter is 1,080 miles, 398 miles of this will be below the center of the umbra, and adding to this the radius of the umbra, 2,930 miles, we have 3,328 miles as the distance along E-E from the lower edge of the moon to the outer edge of the umbra. Dividing this by 2,160, the moon's diameter, we have 1.541 as the magnitude of the eclipse, as shown in the table.

The greatest magnitude possible is about 1.83, and this is the case when the center of the moon and center of the umbra coincide. Under such a condition, conjunction in right ascension, middle of the eclipse, and full moon, all happen at the same instant. This was very nearly the case in the summer eclipse of 1888, when there were only 18-second intervals of time between conjunction, middle of eclipse, and full moon.

THE PLANETS IN AUGUST

Mercury and *Mars* are too near the sun to be of interest.

Venus and *Jupiter,* in Gemini, will be in fairly close conjunction early on the morning of August 2nd. The separation will be 21 minutes with Venus to the south. The actual conjunction will take place at 0 hours, but there will be only a slight change in relative positions when the planets rise at 3:45 a.m. Both are at approximately their faintest magnitudes for 1942, *Venus,* –3.4, and *Jupiter,* –1.5, but bright enough to make a brilliant sight before dawn.

Saturn and *Uranus* are in Taurus and both rise before midnight at the end of the month.

PHASES OF THE MOON

Last quarter	August 3, 7:04 p.m.
New moon	August 11, 10:28 p.m.
First quarter	August 19, 7:30 a.m.
Full moon	August 25, 11:46 p.m.

AUGUST METEORS

The Perseid meteor shower is due about the middle of the month. See "Beginner's Page" for details.

Answers to DO YOU KNOW?

(Questions on page 17)

I. 1, b; 2, b; 3, a; 4, c; 5, b; 6, a; 7, d; 8, a; 9, b; 10, c.

II. Taking the pairs in the order of the terms in the second column, the answers are: .073, 3.34, 2,160, .0549, .0123, 18.6, 25,800, 27.32, .16, 1.5.

III. South is at the top. Distances from bottom and right side, respectively, in inches, are: 1, 1 & 1¼; 2, 2 & 1⅜; 3, 1⅝ & 1⅛; 4, ⅞ & 1⅝; 5, 2⅝ & ½; 6, 2 & 3⅜; 7, 1¼ & ⅝; 8, 2½ & 2⅝; 9, ⅞ & ⅞; 10, 3½ & 1⅜.

OCCULTATIONS—AUGUST, 1942

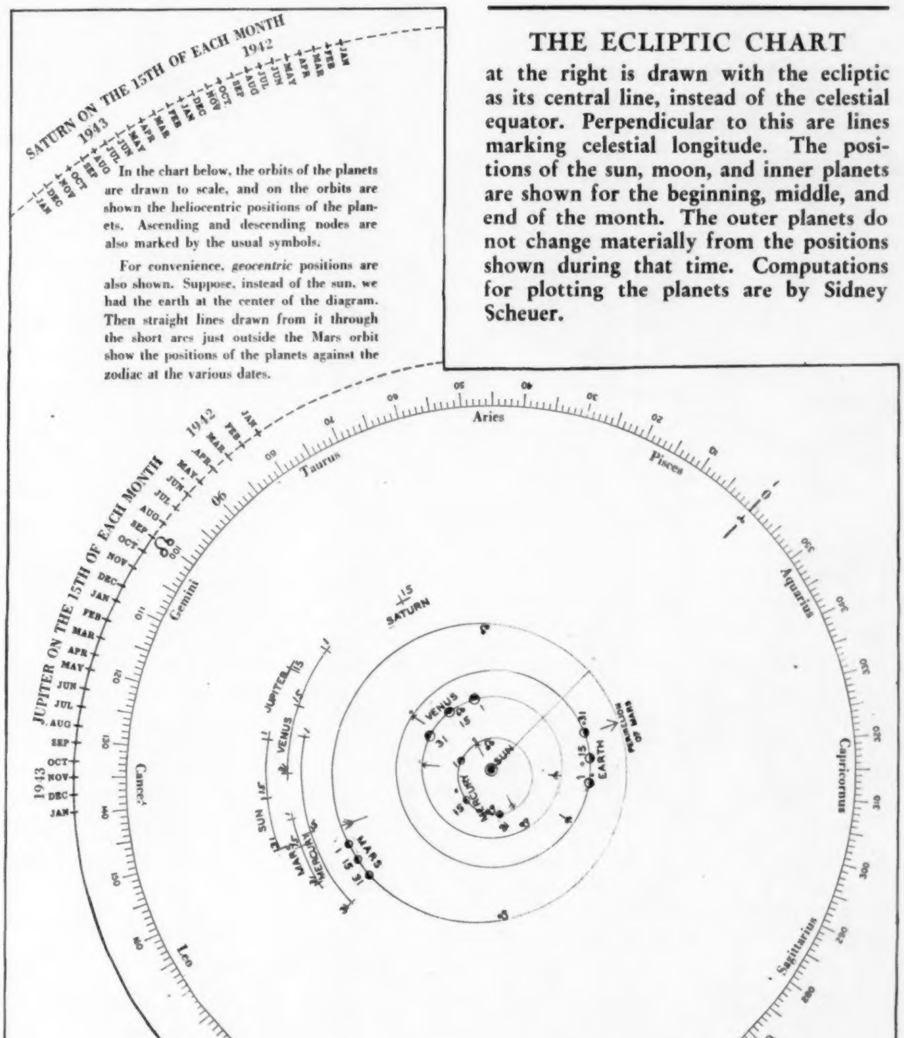
Local station, lat. 40° 48′.6, long. 4h 55.8m west.

Date	Mag.	Name	Immersion	P.*	Emersion	P.*
Aug. 6	5.8	89 Tauri	2:17.3 a.m.	110°	3:06.2 a.m.	221°
22	6.4	226 B Sagittarii	11:15.5 p.m.	105°	0:24.1 a.m. (23)	237°
27	6.3	4 Ceti	10:30.8 p.m.	68°	11:40.6 p.m.	248°
27	6.3	5 Ceti	10:49.7 p.m.	57°	0:00.7 a.m. (28)	257°
31	4.4	μ Ceti	2:55.3 a.m.	105°	3:58.5 a.m.	205°
31	6.2	BD +12° 477	11:09 p.m.	76°	0:06.9 a.m. (1)	248°

* P is the position angle of the point of contact on the moon's disk measured eastward from the north point.

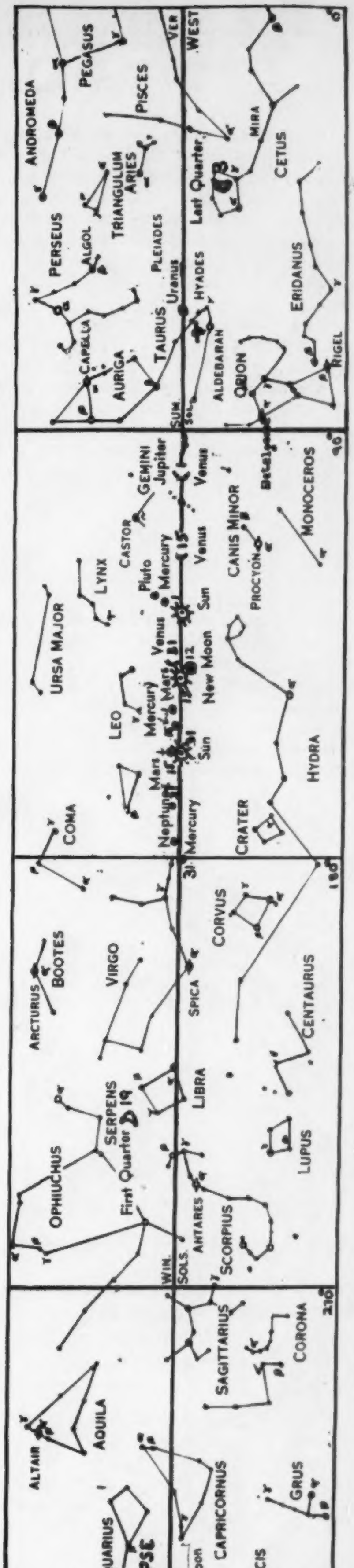
On August 22nd at 9:37.7 p.m., the star d Sagittarii, magnitude 5.0, will be in conjunction with the moon at our local station. At that moment, the star will be two per cent of the moon's diameter north of the moon's edge, and since the position angle of the moon's axis will be 352 degrees, the conjunction will be on a line from the moon's center through the craters Archimedes and Pluto. Computing the circumstances of this phenomenon along the diagonal line running from New York City to Washington, D. C., we find that at Trenton, N. J., the separation will be only one per cent. At Elkton, Md., the star will just graze the moon's edge at 9:35 p.m., the instant of conjunction. However, due to the apparent sloping path of the star, there will be a momentary occultation just prior to the conjunction at this station. At Wilmington, Del., the star will be entirely clear of the moon, but at Havre de Grace, Md., there will be a slight occultation. At Washington, D. C., there will be an occultation lasting 17.4 minutes.

Although at latitude +40° there will be no occultation at the Atlantic seaboard, in the Mississippi valley there will be a decided occultation in this latitude. At standard station long. +91°, lat. +40°, it will last 23.2 minutes; immersion at 7:55.8 p.m., C.W.T., emersion, 8:19 p.m.



THE ECLIPTIC CHART

at the right is drawn with the ecliptic as its central line, instead of the celestial equator. Perpendicular to this are lines marking celestial longitude. The positions of the sun, moon, and inner planets are shown for the beginning, middle, and end of the month. The outer planets do not change materially from the positions shown during that time. Computations for plotting the planets are by Sidney Scheuer.



THE APPARENT POSITIONS IN THE HEAVENS OF THE SUN, MOON, AND PLANETS.

The Starry Heavens in August

By Leland S. Copeland

Our cosmic homeland bends over us in mid-August, when the brightest part of the Milky Way lies across the meridian at 10 p.m., War Time. From Cassiopeia to Scorpius a glorious white arch overhangs the earth. Continuing southward, it dips behind the horizon on its way to the Keyhole nebula in Carina and the Coalsack in Crux.

As we gaze upward, we notice that a black serpentine lane splits the Milky Way from the top of Cygnus to the Scorpion's tail. On the western side of this rift can be seen the Cygnus star cloud, wrapped around the shaft of the Northern Cross; the Door cloud, swinging outward from ζ and ε in Aquila to the head of Ophiuchus; and the broad, subdued mass from Serpens to the main stars of Scorpius. On the brighter eastern side can be observed a long, thin segment from Cygnus through Aquila, Barnard's Gem cloud in Scutum, and the great Sagittarius cloud.

At the lower tip of the Door cloud is the Bull of Poniatowski, east of the head of Ophiuchus. This choice little asterism, named in memory of a brave Polish count, is a miniature of the V-shaped face of Taurus.

Not only can we see the middle layer of our own universe, resembling the rifts shown in photographs of edge-on galaxies, but we are permitted, with unaided eyes or an opera glass, to glimpse a dark nebula. It is almost the "X" that marks the center of our galaxy, and it lies between M6 and θ Ophiuchi, very close to θ. Let us call it the Pipe nebula, though whether it represents the briar of Hubble or the meerschaum of Einstein is one of the unsettled problems of amateur astronomy.

The richest field for amateur telescopes lies in and around Sagittarius. Included are M17, beautiful Horseshoe or Omega nebula; little Sagittarius cloud, a cloth of stars containing cluster M24; M8, Lagoon nebula with cluster; M20, Trifid nebula; M22 and M55, splendid globulars; and M6 and M7 of Scorpius, sparkling open clusters. Between M8 and M20 is the winter solstice, where the sun pauses at Christmas time.

In the northeast look for Cassiopeia and Andromeda, and in the east, high up, for the Great Square of Pegasus. Spica is setting, followed by Arcturus, and west of the meridian are starry Hercules and the shining frame of Ophiuchus.

The Man with the Snake

When the Medical Corps of the United States Army adopted as its symbol the caduceus, it forgot to consult amateur astronomers and classic mythologists. Through error the double-snake wand was chosen instead of the sign of Asclepius (Roman Aesculapius), a single serpent entwining a club-like staff. The caduceus, emblem of Mercury, had nothing to do with the healing art.

Amateurs know that Ophiuchus or Serpentarius, as Asclepius is called in sky lore, holds a single serpent, which stretches from Corona Borealis to Aquila. To distinguish this stellar reptile from Ophiuchus, some astronomers have cut it into two parts, Serpens Caput and Serpens Cauda. The snake bearer himself towers above the Scorpion, on which he has planted one foot, and stands cheek by cheek with inverted Hercules.

Milton spoke of "Ophiuchus huge in the arctic sky." He must have slipped in astrography, because the greater part of the constellation lies south of the celestial equator. The head and shoulders of the snake holder, north of the equator, are a large triangle with α at the apex, β and γ at the eastern corner, and κ and ι at the western. The star λ connects the head with one hand, ε and δ, gripping the big serpent.

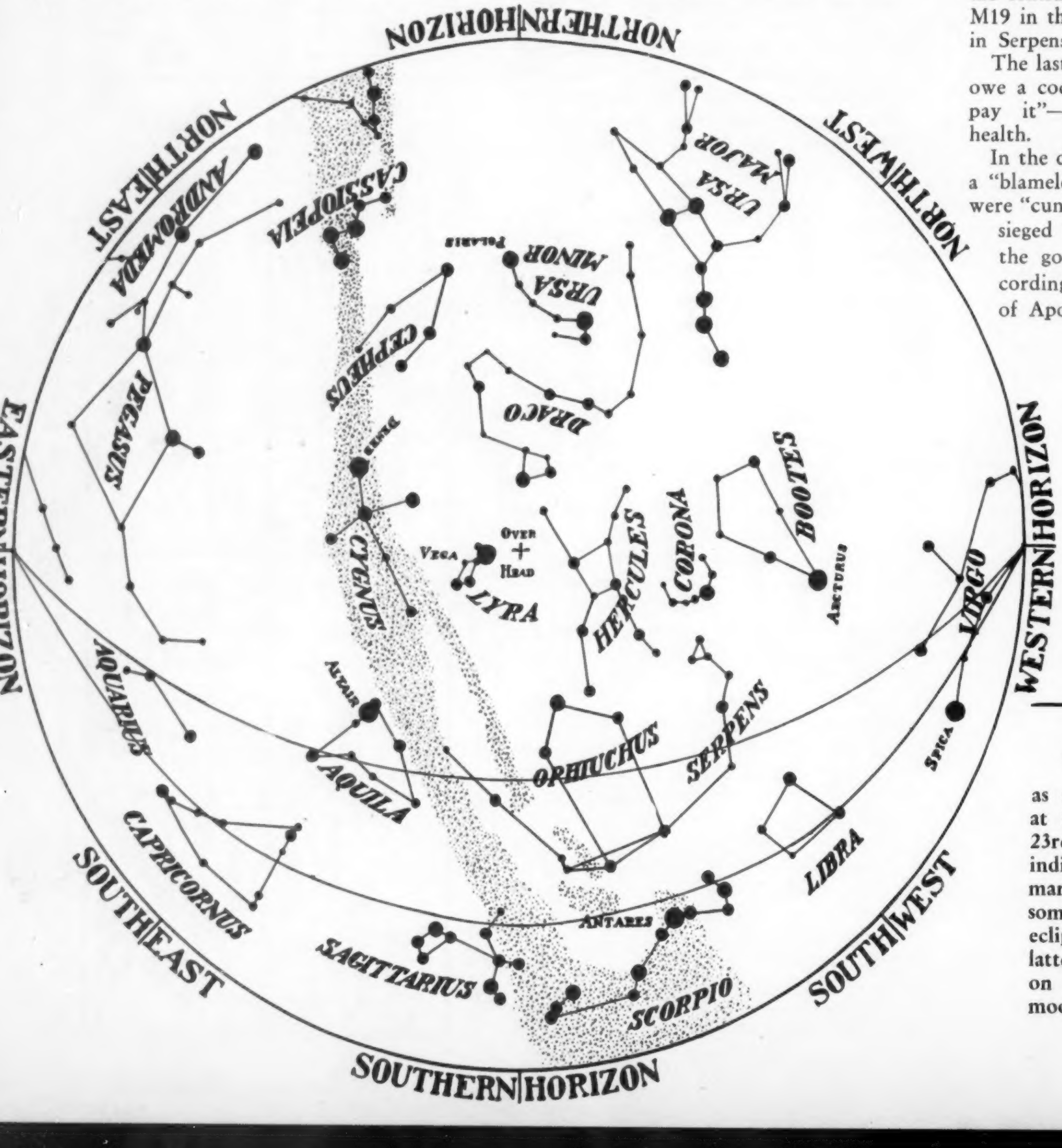
Five stars, resembling an hourglass, form the head of Serpens, which can be found under Corona Borealis. The tail of the snake runs backward up the great rift of the Milky Way.

Sky wonders inviting amateur telescopes include M5, globular cluster in Serpens Caput; globulars M12, M10, and M14, in the central part of Ophiuchus, and M9 and M19 in the southern; and M16, open cluster in Serpens Cauda.

The last words of Socrates were, "Crito, I owe a cock to Asclepius; do not forget to pay it"—a thank offering for restored health.

In the days of Homer, Asclepius was only a "blameless physician," two of whose sons were "cunning leeches" in the army that besieged Troy. With the passage of years the good physician became a god. According to the ancients, he was the son of Apollo and the nymph, Coronis, and he was educated in the medical art by Chiron, wisest and only well-behaved centaur, whose celestial memorial is Sagittarius. Many temples on Grecian hills and beside mineral springs honored the great healer.

He grew in skill—or at least in legend—until he was able to raise the dead. Because Pluto complained, Zeus hurled a thunderbolt. So Asclepius was slain, but by Apollo's grace he shines among the stars.



THE STARS FOR AUGUST

as seen from mid-northern latitudes at 10 p.m., Aug. 7th; 9 p.m., Aug. 23rd. Magnitudes of the stars are indicated by the sizes of the disks marking the stars, and the names of some of the brighter stars appear. The ecliptic and equator are shown, the latter farthest to the south. See chart on the "Observer's Page" for sun, moon, and planet positions.

THE list of double stars in the adjoining columns is the second in a series which will cover the entire sky, furnishing amateurs with complete observing data on bright, resolvable binaries. See the "Observer's Page" in the issues of June and July, 1942, for an article on the visual observation of double stars. The list for 12h to 16h appeared in the June issue; the next will appear in October, covering 20h to 24h.

The columns are: star designation; right ascension, declination (1950); photometric magnitudes; "Aitken" visual magnitudes; spectral classes; separation; position angle.

A and *B* are the brighter (primary) star and fainter star, respectively. Where available, the photometric magnitudes are given to two places; magnitudes in parentheses are estimated or uncertain. "Aitken" magnitudes are from visual observations and often differ greatly from the photometric figures, therefore the former are useful chiefly to indicate the relative magnitude difference between the components.

The data for this table is compiled from the Boss *General Catalogue;* Aitken's *Double Star Catalogue;* and Innes' *Southern Double Stars.*

HERE AND THERE WITH AMATEURS

will henceforth appear every other month, alternating with the list of double stars in the adjoining column. Amateur societies should inform *Sky and Telescope* of any changes in meeting times and places, so that "Here and There with Amateurs" may carry correct information.

LIST OF DOUBLE STARS—R. A. 16h to 20h

	Star	*R. A.* *h*	*m*	*Dec.* °	′	*Photometric mag.* *A B*	*A*	*B*	*Aitken mag.*	*Spectra* *A*	*B*	*Sep.* ″	*P.A.* °
Aquila	5	18	43.9	− 1	1	5.68	....	....	5.6—7.4	A0	....	13.0	121
Corona Borealis	σ	16	12.8	+33	59	5.36	5.76	6.66	5.0—6.1	G0	F6	5.2	(225)
Cygnus	β	19	28.7	+27	51	(3.1)	3.24	5.36	3.0—5.3	K0	B9	34.6	55
	δ	19	43.4	+45	0	2.97	....	....	3.0—7.9	A0	....	2.0	250
	17	19	44.5	+33	37	5.03	....	(9.0)	5.1—8.1	F5	....	25.9	70
Draco	η	16	23.3	+61	38	2.89	....	....	2.1—8.1	G5	K1	5.4	142
	17	16	35.0	+53	1	5.56	....	6.58	5.0—6.0	A2	....	3.6	111
	μ	17	4.3	+54	32	5.06	5.80	5.83	5.0—5.1	F5	F6	2.3	118
	ψ	17	42.8	+72	10	(4.6)	4.90	6.07	4.0—5.2	F5	F5	30.6	15
	ο	18	50.5	+59	20	4.78	....	....	4.6—7.6	K0	....	35.0	325
	ε	19	48.4	+70	8	3.99	....	....	4.0—7.6	K0	F6	3.2	12
Hercules	κ	16	5.8	+17	11	(5.0)	5.34	6.52	5.0—6.0	G5	G5	29.4	12
	ζ	16	39.4	+31	42	3.00	....	....	3.0—6.5	G0	....	(1.5)	(113)
	α	17	12.4	+14	27	(3.3)	3.48	5.39	3.0—6.1	Mb	Mb	4.6	110
	δ	17	13.0	+24	54	3.16	....	....	3.0—8.1	A2	....	11.0	206
	ρ	17	22.0	+37	11	(4.1)	4.52	5.47	4.0—5.1	A0	A0	4.0	314
	μ	17	44.5	+27	45	3.48	....	....	3.8—	G5	M3	33.0	244
	95	17	59.4	+21	36	(4.4)	5.13	5.21	4.9—4.9	A3	G5	6.3	259
	100	18	5.8	+26	6	(5.2)	5.92	6.00	5.9—5.9	A3	A3	14.1	182
Lyra	ε¹	18	42.7	+39	37	(4.7)	5.06	6.02	4.6—6.3	A3	A3	3.1	0
	ε²	18	42.7	+39	34	4.50	5.14	5.37	4.9—5.2	A5	A5	2.5	115
	β	18	48.2	+33	18	(3.4)	Var.	7.78	3.0—6.7	B8	B8	46.0	149
	η	19	12.0	+39	4	4.46	....	(9.0)	4.0—8.1	B3	....	28.2	83
Ophiuchus	ρ	16	22.6	−23	20	(4.8)	5.22	5.92	5.0—6.0	B5	B5	3.4	346
	λ	16	28.4	+ 2	6	3.85	....	....	4.0—6.1	A0	....	0.5	(125)
	36	17	12.3	−26	32	(4.6)	5.29	5.33	6.0—6.0	K0	K0	4.3	(167)
	39	17	15.0	−24	14	(5.2)	5.39	6.90	6.0—7.0	K0	K0	11.0	355
	61	17	42.1	+ 2	36	(5.7)	6.25	6.64	6.2—6.5	A0	A0	21.0	93
	τ	18	0.4	− 8	11	4.88	5.34	6.04	5.0—5.7	F0	F0	2.2	266
	70	18	2.9	+ 2	31	4.07	....	....	4.1—6.1	K0	K6	6.7	(120)
Sagittarius	μ	18	10.8	−21	4	4.01	....	....	4.0–11.0	B8p	....	17.2	260
	η	18	14.2	−36	47	3.16	....	....	3.0—9.2	Mb	....	3.7	102
Scorpius	β	16	2.5	−19	40	(2.7)	2.90	5.06	2.0—6.0	B1	B1	13.7	23
	σ	16	18.1	−25	28	3.08	....	....	3 −10	B1	....	20.5	272
	α	16	26.3	−26	19	1.22	....	....	1.0—6.5	Ma	A3	3.2	273
Serpens	θ	18	53.7	+ 4	8	(4.1)	4.50	5.37	4.0—4.2	A5	A5	22.3	104

★ ★

Planetarium Notes

Sky and Telescope is official bulletin of the Hayden Planetarium in New York City and of the Buhl Planetarium in Pittsburgh, Pa.

★ **THE BUHL PLANETARIUM** presents *in August,* TELLING TOMORROW'S WEATHER.

Many people's personal contacts with some sciences are rare—but not with the science of the weather. The laboratory of the weatherman is the air we breathe, the sky above us. It has been said indeed that no other factor in life affects a person so continuously and importantly as weather. Since in wartime every man must be his own weather prophet, the Buhl Planetarium this month presents visually in its man-made sky a large number of familiar weather portents, and enables us to distinguish between the true and the false. Experiencing a variety of weather in the span of some 40 hours, visitors are shown especially the prime role played by different types of clouds in telling us what sort of weather is around the corner—the "mare's-tails" and "feather clouds," the beautiful bunchy cumulus clouds, the "curdled sky" and "mackerel sky" and others. We discover that while some of the time-honored weather adages (a few of which were being quoted as early as 4000 B.C.) are still good weather science today, others are not.

★ **THE HAYDEN PLANETARIUM** presents *in August,* ECLIPSES, ANCIENT AND MODERN. *(See page 3.)*

In September, AUTUMN SKIES.

Today there is an increased interest in learning the stars. To identify the stars is a part of the navigator's technique. He must learn to point them out and to know their names in order to find them in his almanac list. The airplane spotter as well must know his sky. In his long lonely vigil the sky offers him something for contemplation. This month we are again studying the ancient constellations and the most up-to-date astronomical information as well. With striking photographs, the mythical figures and the Planetarium projector will show us the autumn sky.

In October, SAILING THE SEVEN SEAS.

Here the Hayden Planetarium will present a colorful pageant of the development of navigation. From ancient days to the present, man has constantly sought new methods for finding his way over the earth. The early Polynesians, the Columbus age of explorers, the windjammer, the modern flying fortress—each had its own techniques. By means of complicated projection, music, and newly-created effects, the story will be unfolded on the Planetarium sky. Nor will the principles of navigation be neglected in this popular story.

★ SCHEDULE BUHL PLANETARIUM

Tuesdays through Fridays........................3 and 8:30 p.m.
Saturdays ....2, 3, and 8:30 p.m.
Sundays and Holidays.........................3, 4, and 8:30 p.m.
(Building closed Mondays)

★ STAFF—*Director,* Arthur L. Draper; *Lecturer,* Nicholas E. Wagman; *Business Manager,* Frank S. McGary; *Public Relations,* John J. Grove; *Curator of Exhibits,* Fitz-Hugh Marshall, Jr.

★ SCHEDULE HAYDEN PLANETARIUM

Mondays through Fridays...................2, 3:30, and 8:30 p.m.
Saturdays ....11 a.m., 2, 3, 4, 5, and 8:30 p.m.
Sundays—Mutual Network Broadcast—Coast-to-Coast..9:30–10 a.m.
Sundays and Holidays...................2, 3, 4, 5, and 8:30 p.m.

★ STAFF—*Honorary Curator,* Clyde Fisher; *Curator,* William H. Barton, Jr.; *Assistant Curators,* Marian Lockwood, Robert R. Coles (on leave in Army Air Corps), John Ball, Jr.; *Staff Assistant,* Fred Raiser; *Lecturers,* Asa Tenney, Charles H. Coles.